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2 My success story  
NEET 2022  
RANK Vatsa Ashish Batra

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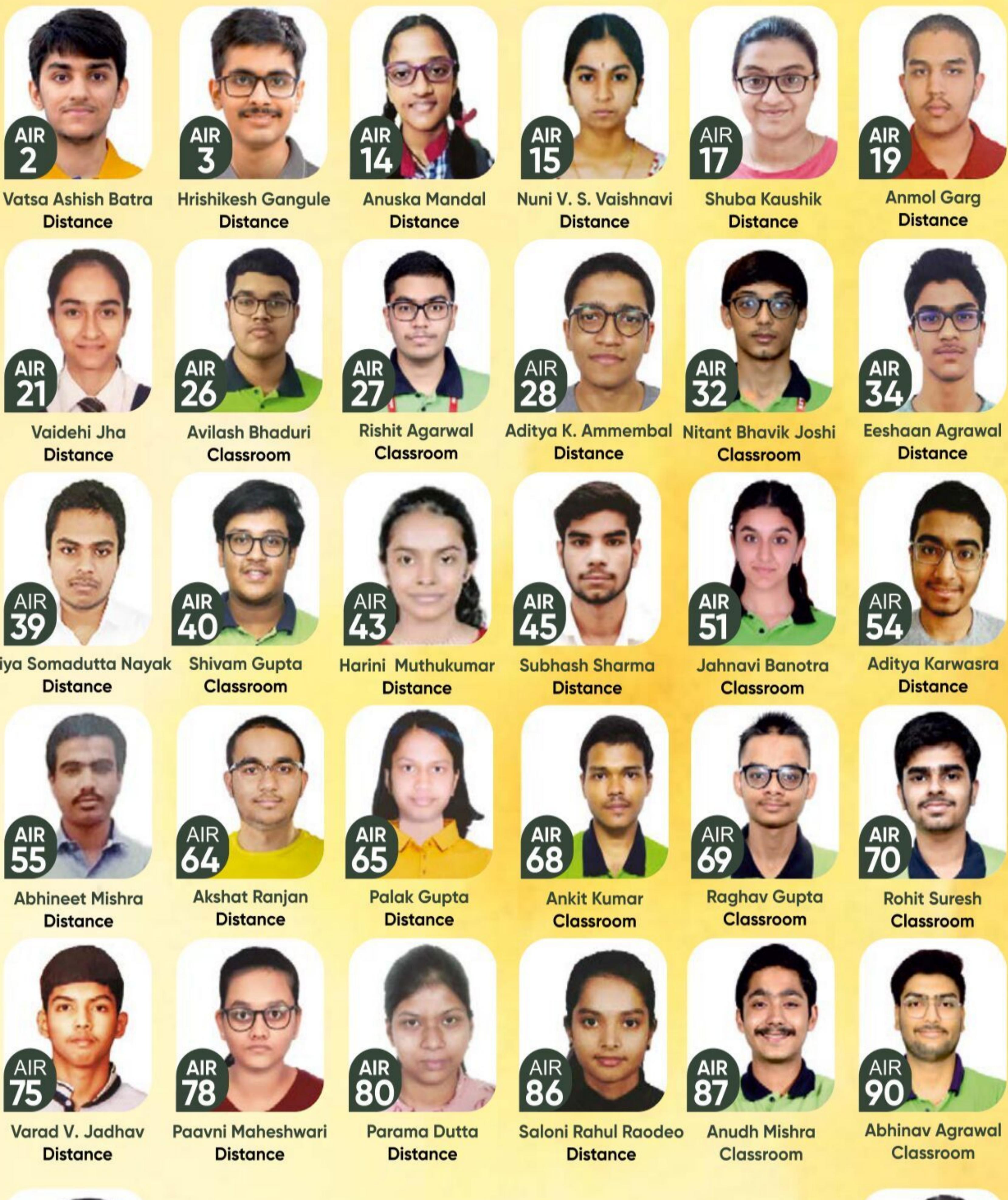
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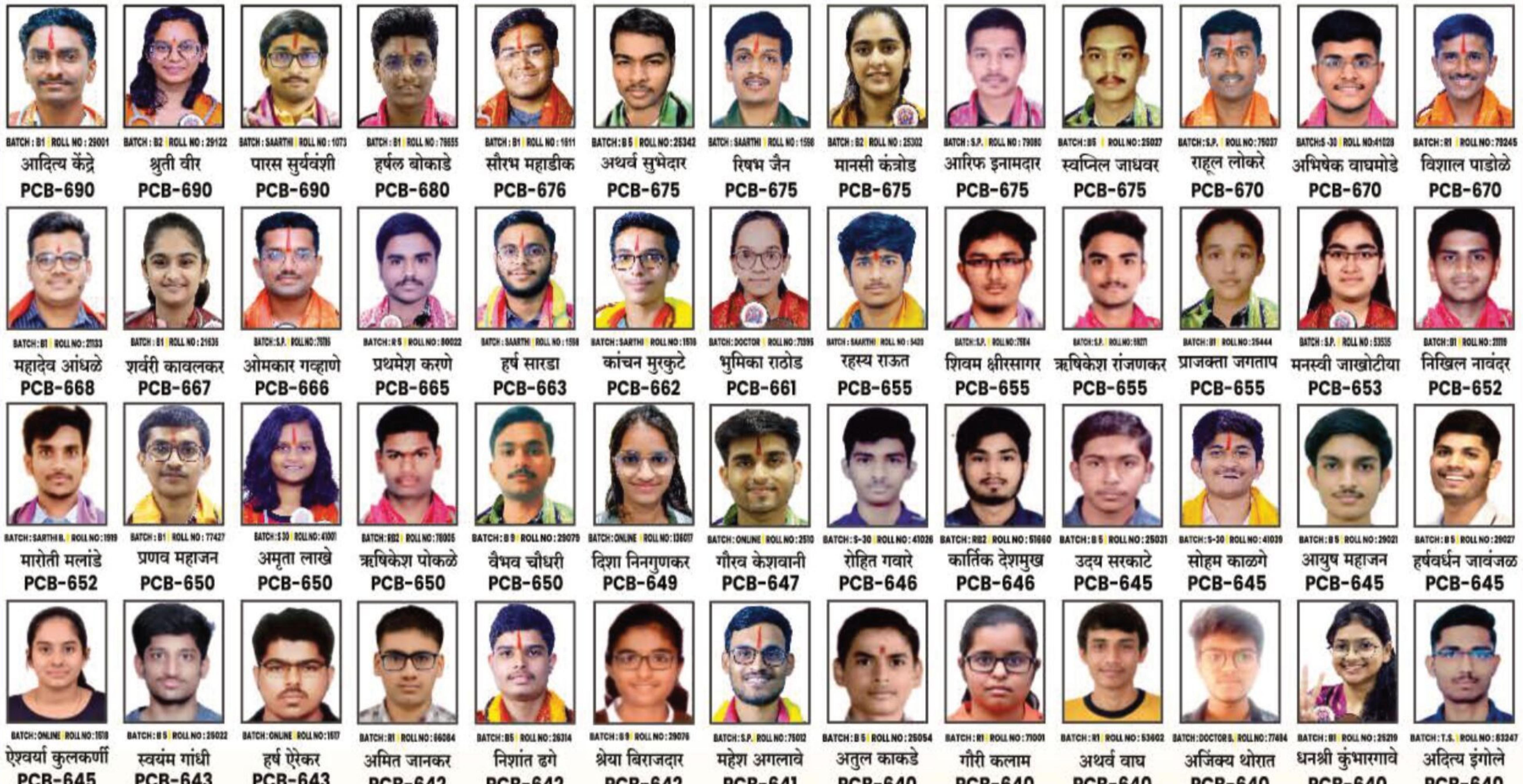


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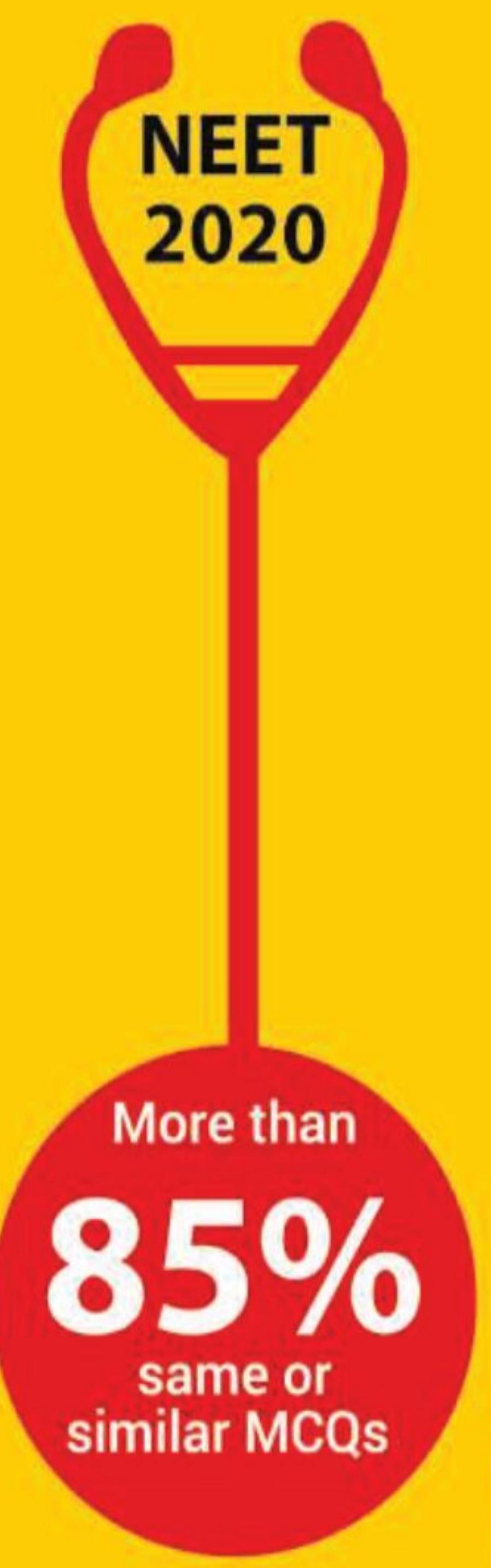
भविष्यातील आव्हानासाठी (NEET / IIT-JEE)

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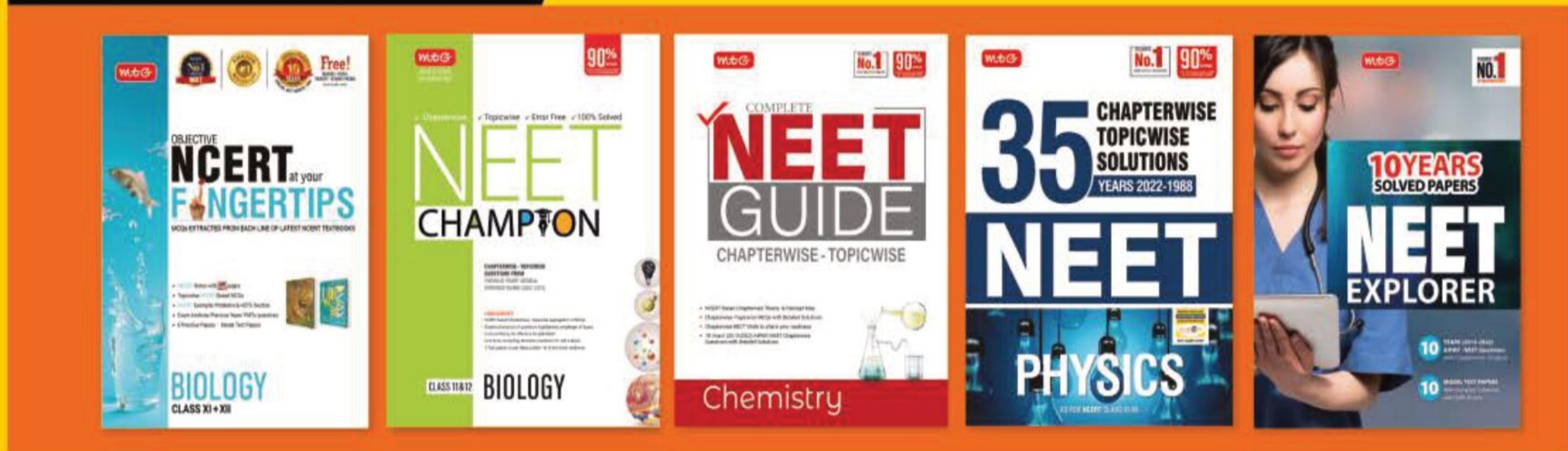
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# CHEMISTRY

# today



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Managing Editor

Mahabir Singh

Editor

Anil Ahlawat

Corporate Office:

Plot 99, Sector 44 Institutional area, Gurugram -122 003 (HR).

Tel : 0124-6601200 e-mail : info@mtg.in website : www.mtg.in

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# My Success Story

## Vatsa Ashish Batra

- **MTG : Why did you choose medical stream?**

Since my childhood, I had a dream to pursue MBBS from AIIMS, New Delhi.

Its my love for the subject which kept me motivated throughout my journey to AIIMS.

- **MTG : What exams have you appeared for and what status/rank you secured in them?**

I have appeared for NEET and scored AIR -2<sup>nd</sup> with 99.99 percentile and score of 715/720.

- **MTG : How did you prepare for the examination?**

I focused on NCERT Textbooks and also teacher's notes and practiced lots of mock tests.

I had one mantra : "Revise whatever is taught in class on the same day."

- **MTG : On which topic and chapters you laid more stress in each subject?**

I paid more attention to chemistry. I was weak in chemistry but I focused more on that as the exam came closer and made it my strength.

- **MTG : How much time does one require for serious preparation for this exam? How did you manage it with school studies?**

Alongwith my coaching classes, I used to devote 4-5 hours for self-study. Gradually I kept on increasing the duration and towards the end, I had increased it to 8-10 hours.

- **MTG : Any extra coaching?**

I have joined Aakash Byju's 2 year classroom programme.

- **MTG : Which subject/topics you were strong/ weak at?**

My weakest subject was chemistry from the beginning, but I didn't let it become my weakness in exam. I focused more on it and made it my most vital subject.

- **MTG : How did you prepare for NEET & other exams?**

In class 11, I was more relaxed and used to study for 4-5 hours a day. As I moved to class 12, I gradually increased time for self study and eventually dedicated 8-10 hours or more.

*What would you suggest to future NEET aspirants in terms of preparation, attitude, etc.*

First of all, you should remember that these 2.5 years of long journey should be consistent. Make a goal for yourself, you know how much you can do. So, it should be a realistic goal and focus on that. What you mainly require is consistency and dedication, that's all.

- **MTG : In your words what are the components of an ideal preparation plan?**

For ideal preparation, just be focused on syllabus and don't let the stress overburden you. Keep revising all topics and make your concepts more clear.

- **MTG : What role did the following play in your success:**

(a) Parents (b) teachers and school

My parents, teachers and coaching institutes all played a great role in helping me bag this success. My teachers were very helpful in giving me extra time if I had any questions or doubts.

- **MTG : Your family background?**

Both my parents are civil engineers and we have been living in Delhi for past two years.

- **MTG : Was this your first attempt?**

Yes! It was first attempt and I made it with positive approach and continuous hard work.

- **MTG : What do you think is the secret of your success?**

I made it very clear from beginning that stress will not dominate my brain. Alongwith studies, I was also involved in extracurricular activities. I've been playing badminton for six years. In addition I also enjoyed music and sometimes basketball also.

- **MTG : Had you not been selected then what would have been your future plan?**

If I had not made it this year, I would have dropped and would appear again next year. I always wanted to study medicine only, as for me it's noble profession.

- **MTG : What advice would you like to give our readers who are MEDICAL/ENGINEERING aspirants?**

My advice to all medical aspirants is to not let the stress decompress your bandwidth. Be focused and consistent in your preparations with full concentration throughout the course. It's a long road to travel, so don't let speed breakers halt your journey.



## UNSCRAMBLE ME

Unscramble the words given in column I and match them with their explanations in column II.

### Column I

1. LURATRTIENCUGFTAONI
2. ARSBS
3. BIHREICED
4. UBLIRNACT
5. SROAPBITNO
6. ARCOMOLMUCEEL
7. TEEPPIT
8. ERIFGNIN
9. LYSOLSOVIS
10. NRRESITGIN

### Column II

- (a) A process in which the substance is uniformly distributed throughout the bulk of the solid.
- (b) A technique in which a high speed centrifuge is used for separating the colloidal particles from the soluble impurities. The sedimentation rate depends on the particle size.
- (c) An alloy of copper (67% Cu) and zinc (33% Zn).
- (d) Large molecule with molecular mass more than 1000.
- (e) Chemical substance which kills unwanted plants or weeds.
- (f) Soft chemical substance used to reduce friction in machines.
- (g) A process which involves the coagulation of powdered substances into a single mass by heating below the melting point of substances.
- (h) The term used to represent a reaction in which the reagent reacts with the solvent.
- (i) The process of purifying or extracting chemical substances from a mixture.
- (j) An apparatus used to transfer a known volume of solution from one container to another.

Readers can send their responses at [editor@mtg.in](mailto:editor@mtg.in) or post us with complete address by 10<sup>th</sup> of every month.  
Winners' names will be published in next issue.

# JEE 2022 SOLVED PAPER ADVANCED

Exam  
held on  
28<sup>th</sup> August

## PAPER-I

### SECTION 1 (MAXIMUM MARKS : 24)

- This section contains EIGHT (08) questions.*
- The answer to each question is a NUMERICAL VALUE.*
- For each question, enter the correct numerical value of the answer using the mouse and the onscreen virtual numeric keypad in the place designated to enter the answer. If the numerical value has more than two decimal places, truncate/round-off the value to TWO decimal places.*
- Answer to each question will be evaluated according to the following marking scheme:*

Full Marks : +3 Only if the correct numerical value is entered;

Zero Marks : 0 In all other cases.

1. 2 mol of  $\text{Hg}_{(g)}$  is combusted in a fixed volume bomb calorimeter with excess of  $\text{O}_2$  at 298 K and 1 atm into  $\text{HgO}_{(s)}$ . During the reaction, temperature increases from 298.0 K to 312.8 K. If heat capacity of the bomb calorimeter and enthalpy of formation of  $\text{Hg}_{(g)}$  are 20.00  $\text{kJ K}^{-1}$  and 61.32  $\text{kJ mol}^{-1}$  at 298 K, respectively, the calculated standard molar enthalpy of formation of  $\text{HgO}_{(s)}$  at 298 K is  $X$   $\text{kJ mol}^{-1}$ . The value of  $|X|$  is \_\_\_\_\_.  
[Given : Gas constant  $R = 8.3 \text{ J K}^{-1} \text{ mol}^{-1}$ ]

2. The reduction potential ( $E^\circ$ , in V) of  $\text{MnO}_{4(aq)}^-/\text{Mn}_{(s)}$  is \_\_\_\_\_.  
[Given :  $E^\circ_{(\text{MnO}_{4(aq)}^-/\text{MnO}_{2(s)})} = 1.68 \text{ V}$ ;

$$E^\circ_{(\text{MnO}_{2(s)} / \text{Mn}_{(aq)}^{2+})} = 1.21 \text{ V};$$

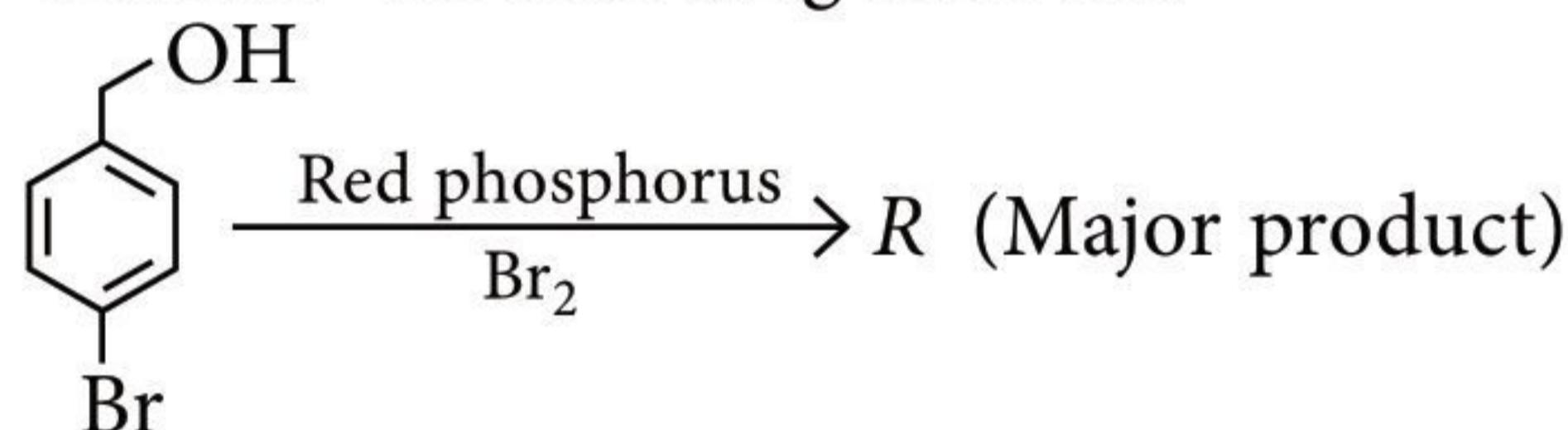
$$E^\circ_{(\text{Mn}_{(aq)}^{2+} / \text{Mn}_{(s)})} = -1.03 \text{ V}]$$

3. A solution is prepared by mixing 0.01 mol each of  $\text{H}_2\text{CO}_3$ ,  $\text{NaHCO}_3$ ,  $\text{Na}_2\text{CO}_3$ , and  $\text{NaOH}$  in 100 mL of water. pH of the resulting solution is \_\_\_\_\_.  
[Given :  $\text{p}K_{a_1}$  and  $\text{p}K_{a_2}$  of  $\text{H}_2\text{CO}_3$  are 6.37 and 10.32, respectively ;  $\log 2 = 0.30$ ]

4. The treatment of an aqueous solution of 3.74 g of  $\text{Cu}(\text{NO}_3)_2$  with excess KI results in a brown solution along with the formation of a precipitate. Passing  $\text{H}_2\text{S}$  through this brown solution gives another precipitate  $X$ . The amount of  $X$  (in g) is \_\_\_\_\_.  
[Given : Atomic mass of H = 1, N = 14, O = 16, S = 32]  
K = 39, Cu = 63, I = 127]

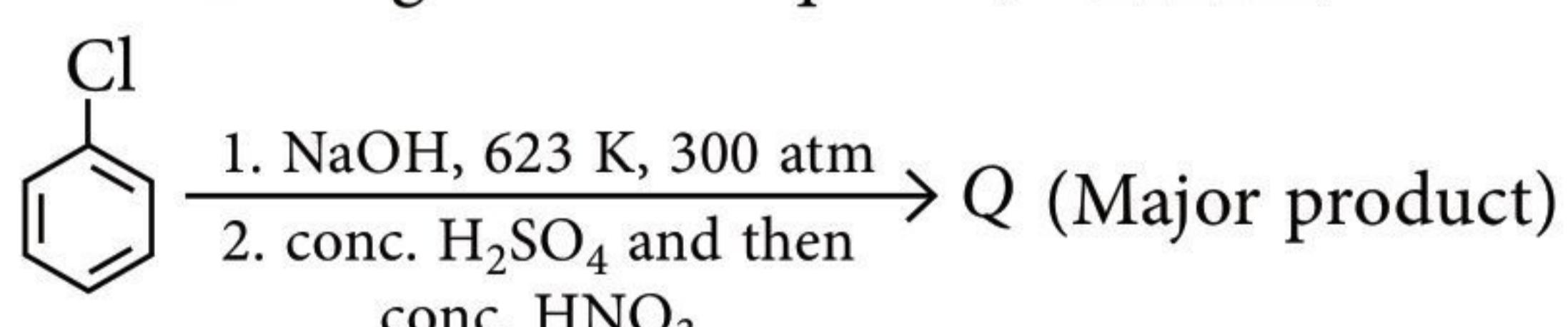
5. Dissolving 1.24 g of white phosphorus in boiling  $\text{NaOH}$  solution in an inert atmosphere gives a gas Q. The amount of  $\text{CuSO}_4$  (in g) required to completely consume the gas Q is \_\_\_\_\_.  
[Given : Atomic mass of H = 1, O = 16, Na = 23, P = 31, S = 32, Cu = 63]

6. Consider the following reaction.

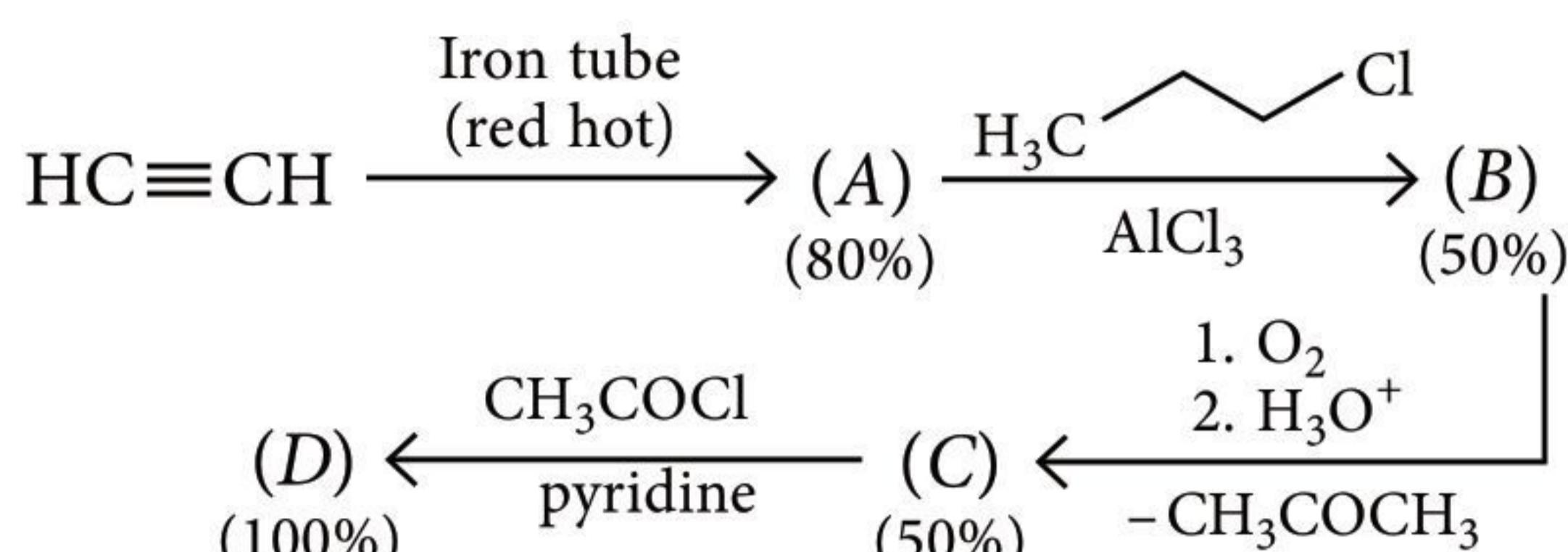


On estimation of bromine in 1.00 g of R using Carius method, the amount of  $\text{AgBr}$  formed (in g) is \_\_\_\_\_.  
[Given : Atomic mass of H = 1, C = 12, O = 16, P = 31, Br = 80, Ag = 108]

7. The weight percentage of hydrogen in Q, formed in the following reaction sequence, is \_\_\_\_\_.  
[Given : Atomic mass of H = 1, C = 12, N = 14, O = 16, S = 32, Cl = 35]



8. If the reaction sequence given below is carried out with 15 moles of acetylene, the amount of the product D formed (in g) is \_\_\_\_\_.  
[Given : Atomic mass of H = 1, C = 12, N = 14, O = 16, S = 32, Cl = 35]



The yields of A, B, C and D are given in parentheses.  
[Given : Atomic mass of H = 1, C = 12, O = 16, Cl = 35]

### SECTION 2 (MAXIMUM MARKS : 24)

- This section contains SIX (06) questions.**
- Each question has FOUR options (a), (b), (c) and (d). ONE OR MORE THAN ONE of these four option(s) is(are) correct answer(s).**
- For each question, choose the option(s) corresponding to (all) the correct answer(s).**
- Answer to each question will be evaluated according to the following marking scheme:**

**Full Marks : +4 ONLY if (all) the correct option(s) is(are) chosen;**

**Partial Marks : +3 If all the four options are correct but ONLY three options are chosen;**

**Partial Marks : +2 If three or more options are correct but ONLY two options are chosen, both of which are correct;**

**Partial Marks : +1 If two or more options are correct but ONLY one option is chosen and it is a correct option;**

**Zero Marks : 0 If none of the options is chosen (i.e., the question is unanswered);**

**Negative Marks : -2 In all other cases.**

**9.** For diatomic molecules, the correct statement(s) about the molecular orbitals formed by the overlap of two  $2p_z$  orbitals is(are)

- $\sigma$  orbital has a total of two nodal planes.
- $\sigma^*$  orbital has one node in the  $xz$ -plane containing the molecular axis.
- $\pi$  orbital has one node in the plane which is perpendicular to the molecular axis and goes through the center of the molecule.
- $\pi^*$  orbital has one node in the  $xy$ -plane containing the molecular axis.

**10.** The correct option(s) related to adsorption processes is(are)

- chemisorption results in a unimolecular layer.
- the enthalpy change during physisorption is in the range of 100 to 140  $\text{kJ mol}^{-1}$ .
- chemisorption is an endothermic process.
- lowering the temperature favours physisorption processes.

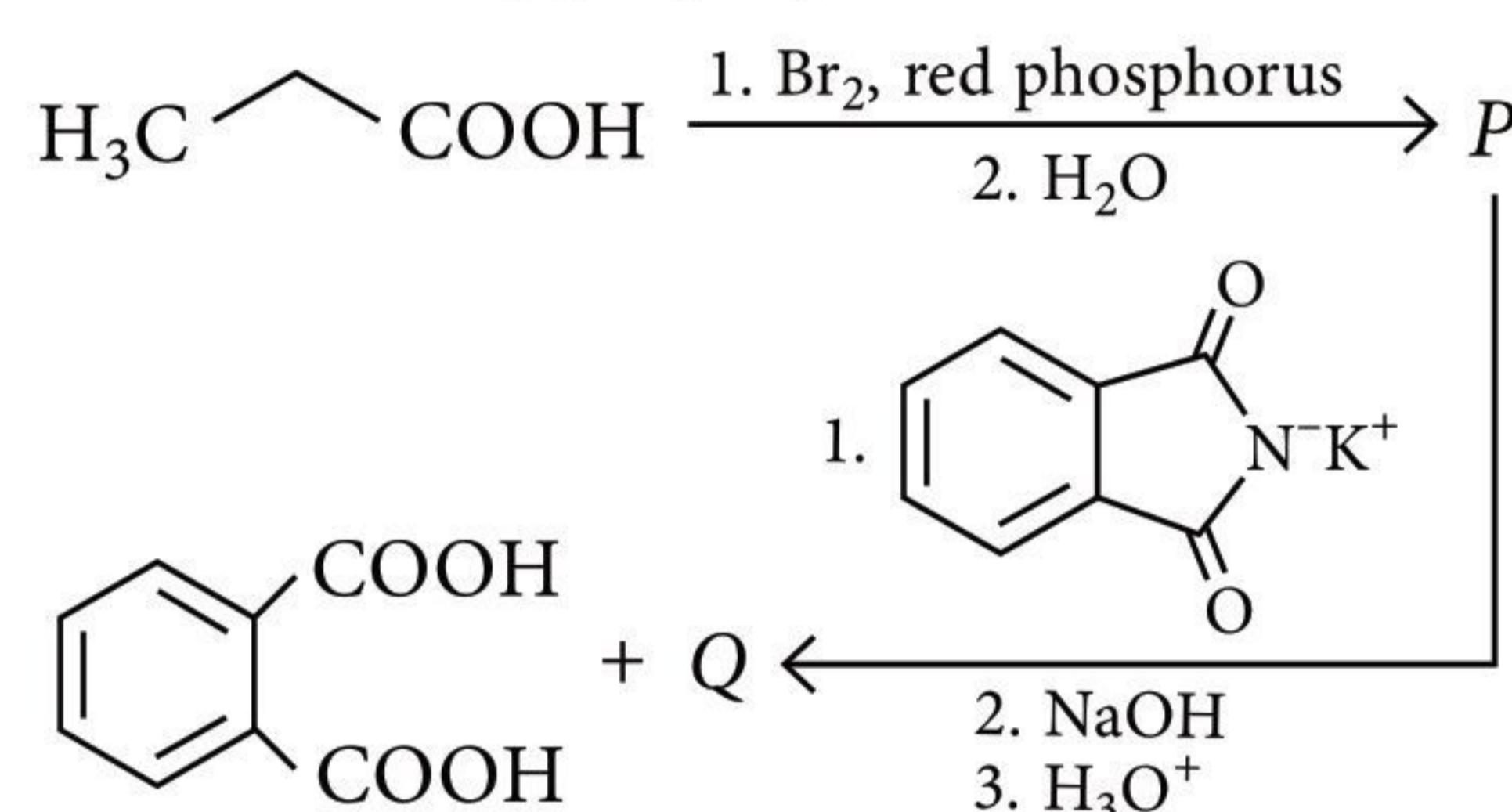
**11.** The electrochemical extraction of aluminum from bauxite ore involves

- the reaction of  $\text{Al}_2\text{O}_3$  with coke (C) at a temperature  $> 2500 \text{ }^\circ\text{C}$
- the neutralization of aluminate solution by passing  $\text{CO}_2$  gas to precipitate hydrated alumina ( $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ )
- the dissolution of  $\text{Al}_2\text{O}_3$  in hot aqueous  $\text{NaOH}$ .
- the electrolysis of  $\text{Al}_2\text{O}_3$  mixed with  $\text{Na}_3\text{AlF}_6$  to give Al and  $\text{CO}_2$ .

**12.** The treatment of galena with  $\text{HNO}_3$  produces a gas that is

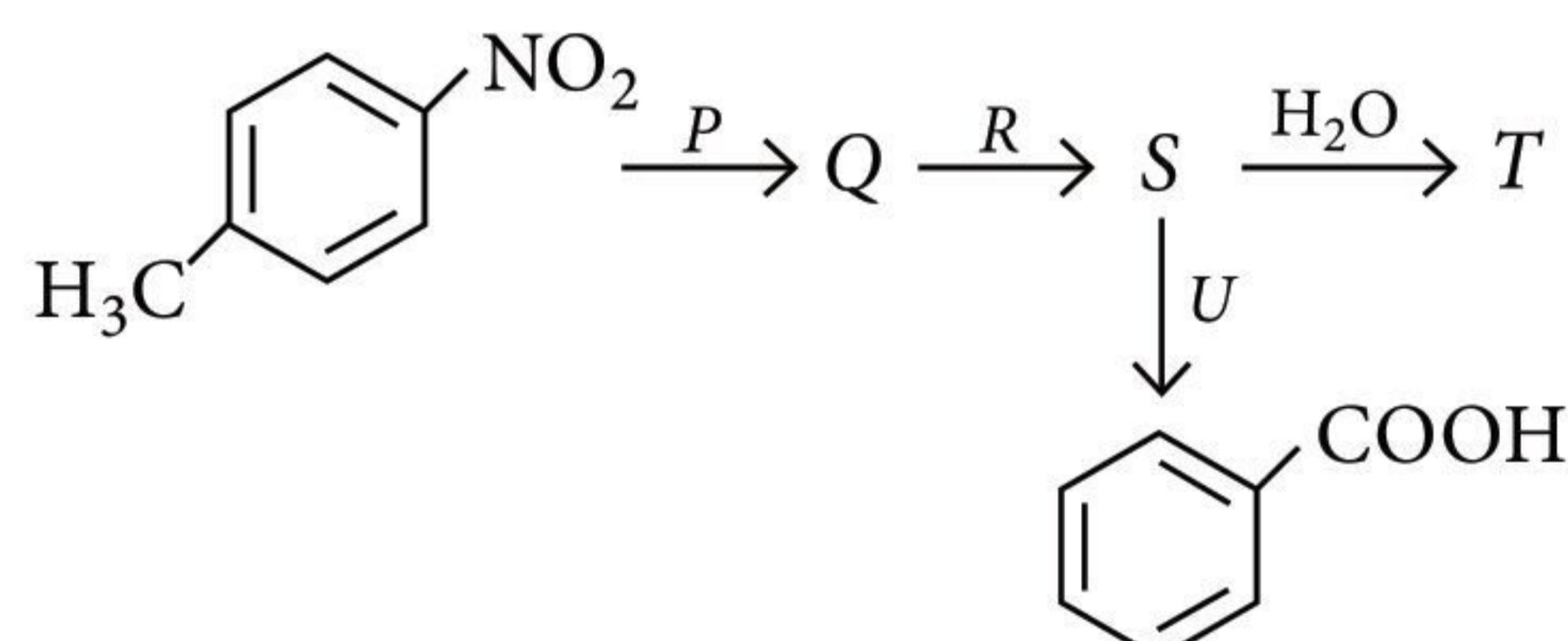
(a) paramagnetic      (b) bent in geometry  
(c) an acidic oxide      (d) colourless.

**13.** Considering the reaction sequence given below, the correct statement(s) is(are)



- P can be reduced to a primary alcohol using  $\text{NaBH}_4$ .
- Treating P with conc.  $\text{NH}_4\text{OH}$  solution followed by acidification gives Q.
- Treating Q with a solution of  $\text{NaNO}_2$  in aq.  $\text{HCl}$  liberates  $\text{N}_2$ .
- P is more acidic than  $\text{CH}_3\text{CH}_2\text{COOH}$ .

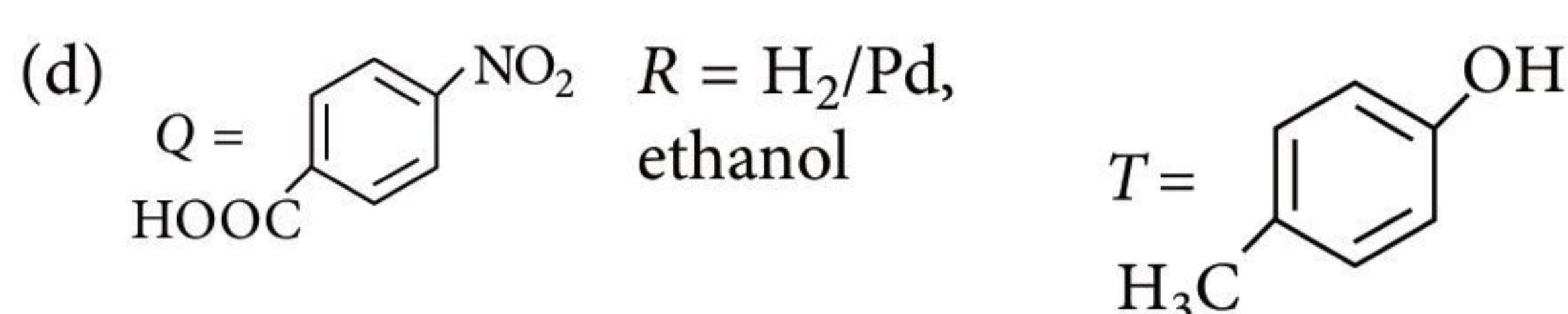
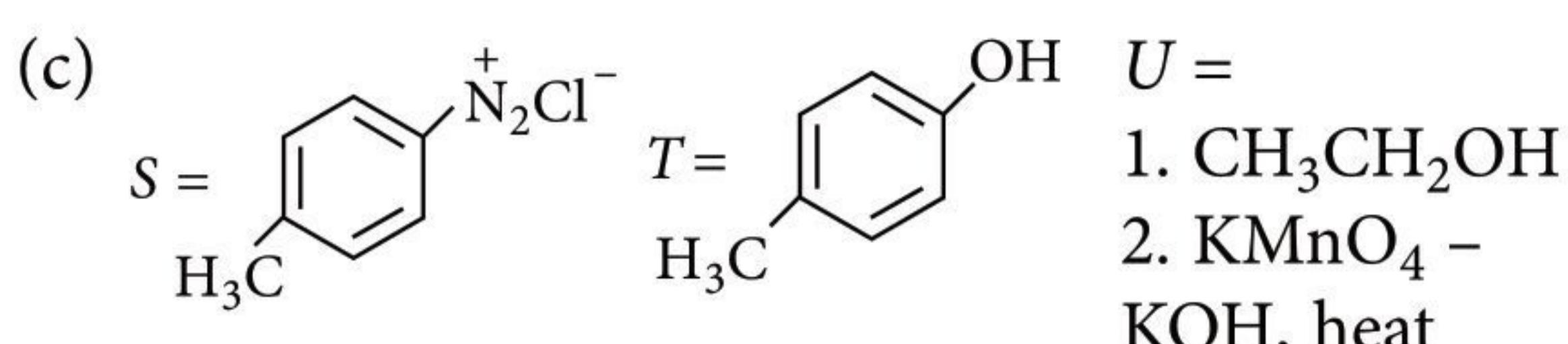
**14.** Considering the following reaction sequence,



the correct option(s) is(are)

(a)  $P = \text{H}_2/\text{Pd}$ ,  $R = \text{NaNO}_2 / \text{HCl}$ ,  $U = 1. \text{H}_3\text{PO}_2 / 2. \text{KMnO}_4 - \text{KOH, heat}$

(b)  $P = \text{Sn}/\text{HCl}$ ,  $R = \text{HNO}_2$ ,  $S = \text{H}_3\text{C} \text{---} \text{C}_6\text{H}_4 \text{---} \text{N}_2^+ \text{Cl}^-$



### SECTION 3 (MAXIMUM MARKS : 12)

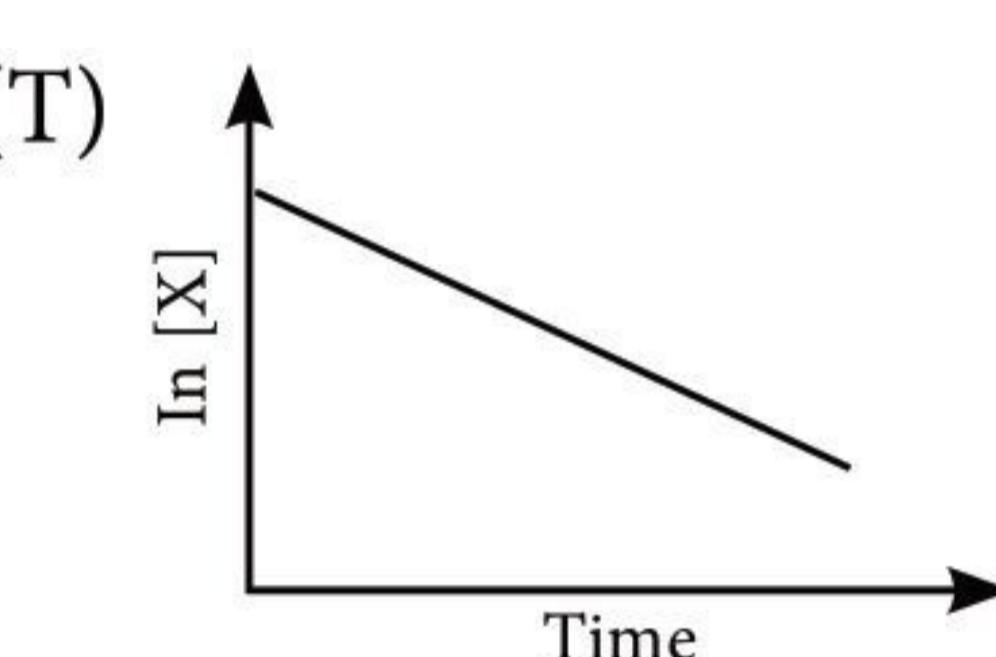
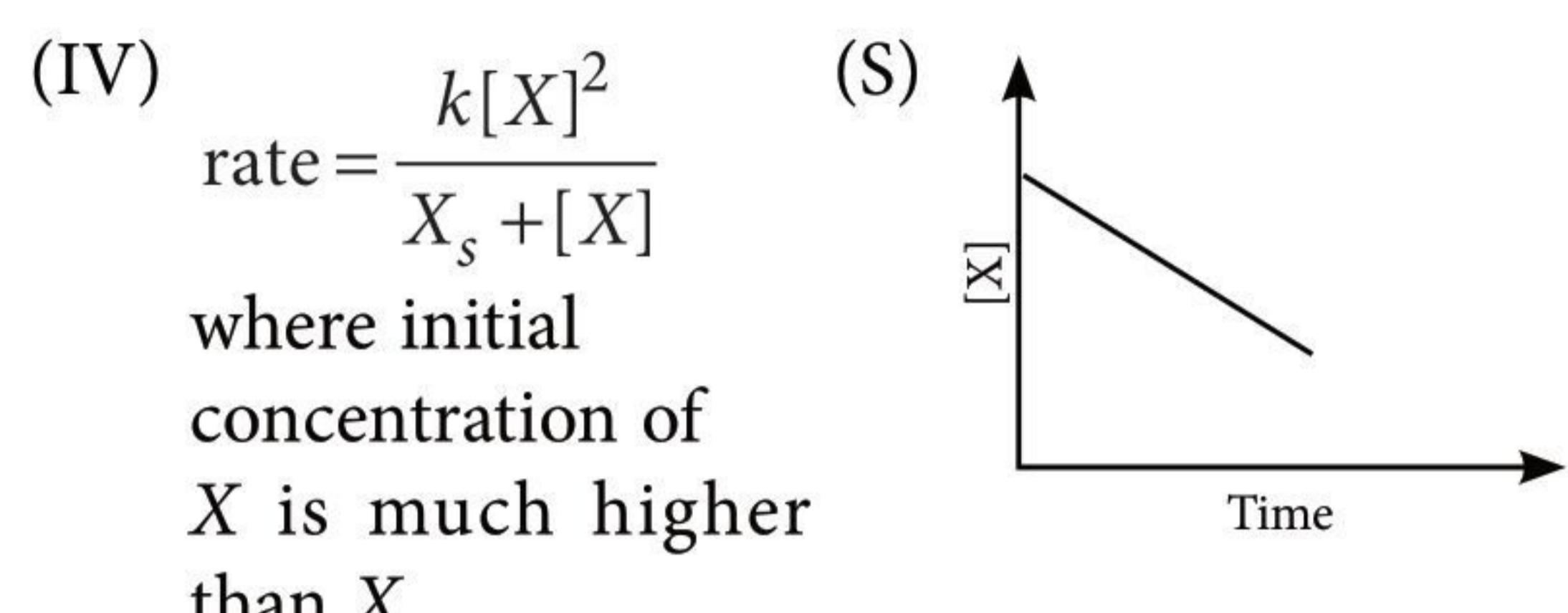
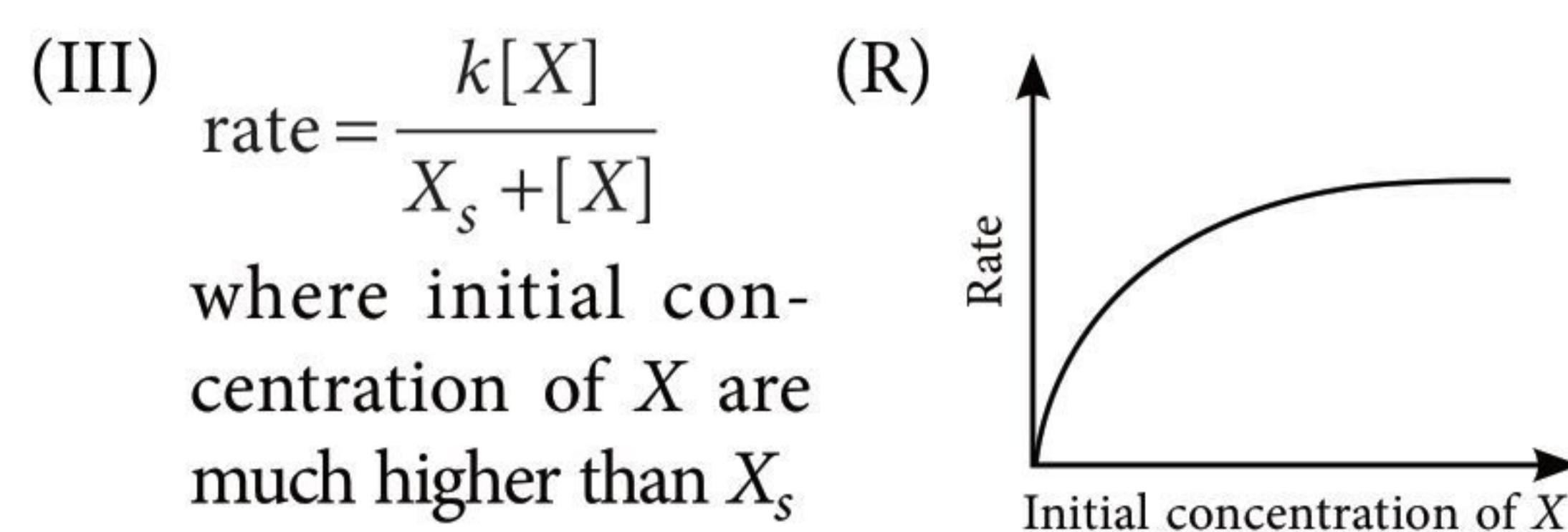
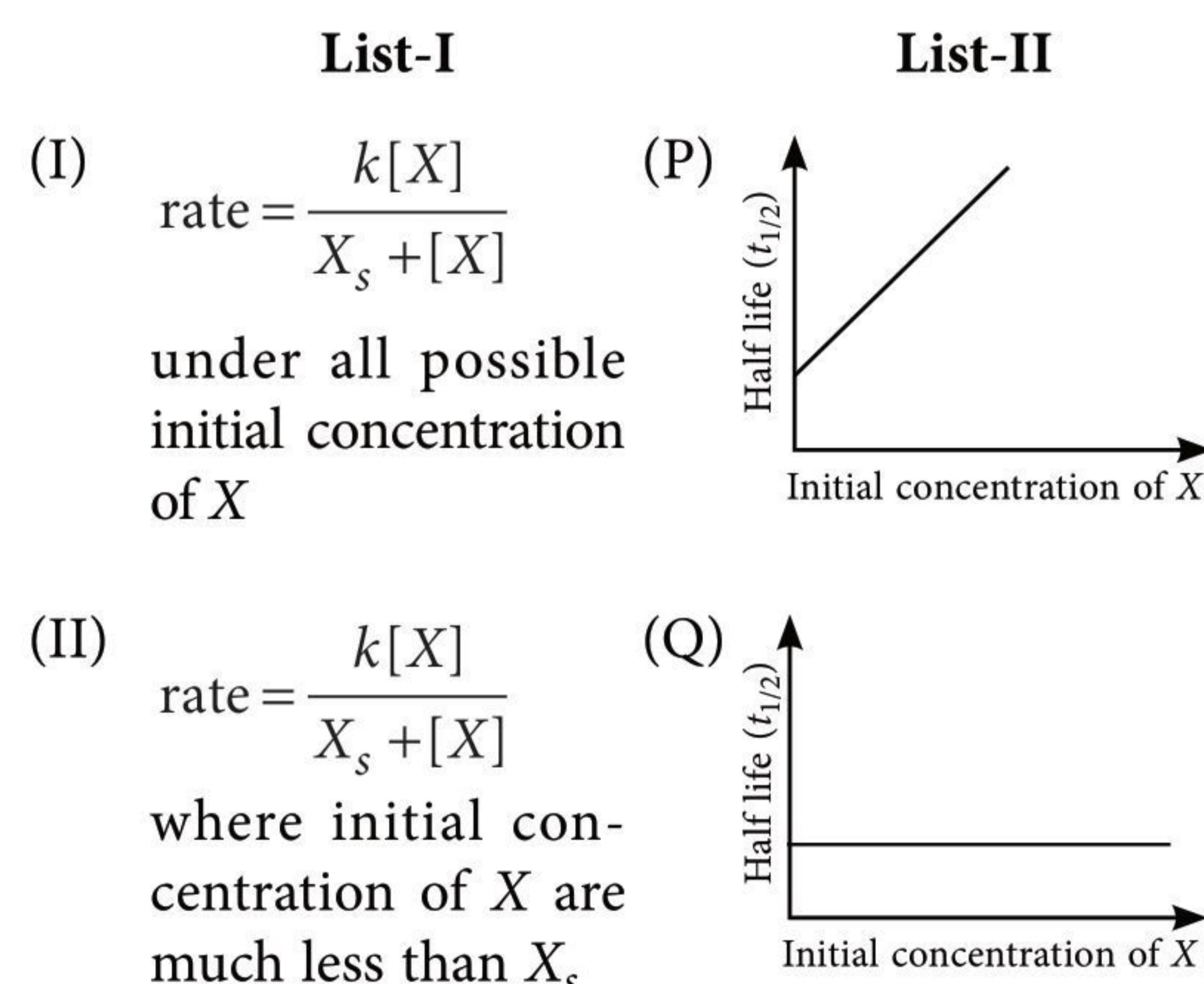
- This section contains FOUR (04) Matching List Sets.
- Each set has ONE Multiple Choice Question.
- Each set has TWO lists: List-I and List-II.
- List-I has Four entries (I), (II), (III) and (IV) and List-II has Five entries (P), (Q), (R), (S) and (T).
- FOUR options are given in each Multiple Choice Question based on List-I and List-II and ONLY ONE of these four options satisfies the condition asked in the Multiple Choice Question.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +3 ONLY if the option corresponding to the correct combination is chosen;

Zero Marks : 0 if none of the options is chosen (i.e., the question is unanswered);

Negative Marks : -1 In all other cases.

15. Match the rate expressions in List-I for the decomposition of  $X$  with the corresponding profiles provided in List-II,  $X_s$  and  $k$  are constants having appropriate units.



(a) (I) – (P), (II) – (Q), (III) – (S), (IV) – (T)  
 (b) (I) – (R), (II) – (S), (III) – (S), (IV) – (T)  
 (c) (I) – (P), (II) – (Q), (III) – (Q), (IV) – (R)  
 (d) (I) – (R), (II) – (S), (III) – (Q), (IV) – (R)

16. List-I contains compounds and List-II contains reactions.

List-I		List-II	
(I)	$\text{H}_2\text{O}_2$	(P)	$\text{Mg}(\text{HCO}_3)_2 + \text{Ca}(\text{OH})_2 \rightarrow$
(II)	$\text{Mg}(\text{OH})_2$	(Q)	$\text{BaO}_2 + \text{H}_2\text{SO}_4 \rightarrow$
(III)	$\text{BaCl}_2$	(R)	$\text{Ca}(\text{OH})_2 + \text{MgCl}_2 \rightarrow$
(IV)	$\text{CaCO}_3$	(S)	$\text{BaO}_2 + \text{HCl} \rightarrow$
		(T)	$\text{Ca}(\text{HCO}_3)_2 + \text{Ca}(\text{OH})_2 \rightarrow$

Match each compound in List-I with its formation reaction(s) in List-II and choose the correct option.

(a) I  $\rightarrow$  (Q); II  $\rightarrow$  (P); III  $\rightarrow$  (S), IV  $\rightarrow$  (R)  
 (b) I  $\rightarrow$  (T); II  $\rightarrow$  (P); III  $\rightarrow$  (Q), IV  $\rightarrow$  (R)  
 (c) I  $\rightarrow$  (T); II  $\rightarrow$  (R); III  $\rightarrow$  (Q), IV  $\rightarrow$  (P)  
 (d) I  $\rightarrow$  (Q); II  $\rightarrow$  (R); III  $\rightarrow$  (S), IV  $\rightarrow$  (P)

17. List I contains metal species and List II contains their properties.

List-I		List-II	
(I)	$[\text{Cr}(\text{CN})_6]^{4-}$	(P)	$t_{2g}$ orbitals contains 4 electrons
(II)	$[\text{RuCl}_6]^{2-}$	(Q)	$\mu(\text{spin-only}) = 4.9 \text{ BM}$
(III)	$[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$	(R)	low spin complex ion
(IV)	$[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$	(S)	metal ion in 4+ oxidation state
		(T)	$d^4$ species

[Given : Atomic number of Cr = 24, Ru = 44, Fe = 26]  
 Match each metal species in List-I with their properties in List-II, and choose the correct option.

(a) (I) – (R, T); (II) – (P, S); (III) – (Q, T), (IV) – (P, Q)  
 (b) (I) – (R, S); (II) – (P, T); (III) – (P, Q), (IV) → (Q, T)  
 (c) (I) – (P, R); (II) – (R, S); (III) – (R, T), (IV) – (P, T)  
 (d) (I) – (Q, T); (II) – (S, T); (III) – (P, T), (IV) – (Q, R)

18. Match the compound in List-I with the observations in List-II and choose the correct option.

List-I		List-II	
(I)	Aniline	(P)	Sodium fusion extract of the compound on boiling with $\text{FeSO}_4$ , followed by acidification with conc. $\text{H}_2\text{SO}_4$ , gives Prussian blue colour.

(II)	<i>o</i> -Cresol	(Q)	Sodium fusion extract of the compound on treatment with sodium nitroprusside gives blood red colour.
(III)	Cysteine	(R)	Addition of the compound to a saturated solution of $\text{NaHCO}_3$ results in effervescence.
(IV)	Capro-lactam	(S)	The compound reacts with bromine water to give a white precipitate.
		(T)	Treating the compound with neutral $\text{FeCl}_3$ solution produces violet colour.

(a) (I) – (P, Q), (II) – (S), (III) – (Q, R), (IV) – (P)  
 (b) (I) – (P), (II) – (R, S), (III) – (R), (IV) – (Q, S)  
 (c) (I) – (Q, S), (II) – (P, T), (III) – (P), (IV) – (S)  
 (d) (I) – (P, S), (II) – (T), (III) – (Q, R), (IV) – (P)

## PAPER - II

### SECTION 1 (MAXIMUM MARKS : 24)

- This section contains EIGHT (08) questions.*
- The answer to each question is a SINGLE DIGIT INTEGER ranging from 0 TO 9, BOTH INCLUSIVE.*
- For each question, enter the correct integer corresponding to the answer using the mouse and the onscreen virtual numeric keypad in the place designated to enter the answer.*
- Answer to each question will be evaluated according to the following marking scheme:*

**Full Marks** : +3 *If ONLY the correct integer is entered;*

**Zero Marks** : 0 *If the question is unanswered;*

**Negative Marks** : -1 *In all other cases.*

1. Concentration of  $\text{H}_2\text{SO}_4$  and  $\text{Na}_2\text{SO}_4$  in a solution is 1 M and  $1.8 \times 10^{-2}$  M, respectively. Molar solubility of  $\text{PbSO}_4$  in the same solution is  $X \times 10^{-Y}$  M. (expressed in scientific notation). The value of Y is \_\_\_\_\_.

[Given : Solubility product of  $\text{PbSO}_4$  ( $K_{sp}$ ) =  $1.6 \times 10^{-8}$ . For  $\text{H}_2\text{SO}_4$ ,  $K_{a_1}$  is very large and  $K_{a_2} = 1.2 \times 10^{-2}$ ]

2. An aqueous solution is prepared by dissolving 0.1 mol of an ionic salt in 1.8 kg of water at 35°C. The salt remains 90% dissociated in the solution. The vapour pressure of the solution is 59.724 mm of Hg. Vapour pressure of water at 35 °C is 60.000 mm of Hg. The number of ions present per formula unit of the ionic salt is \_\_\_\_\_.

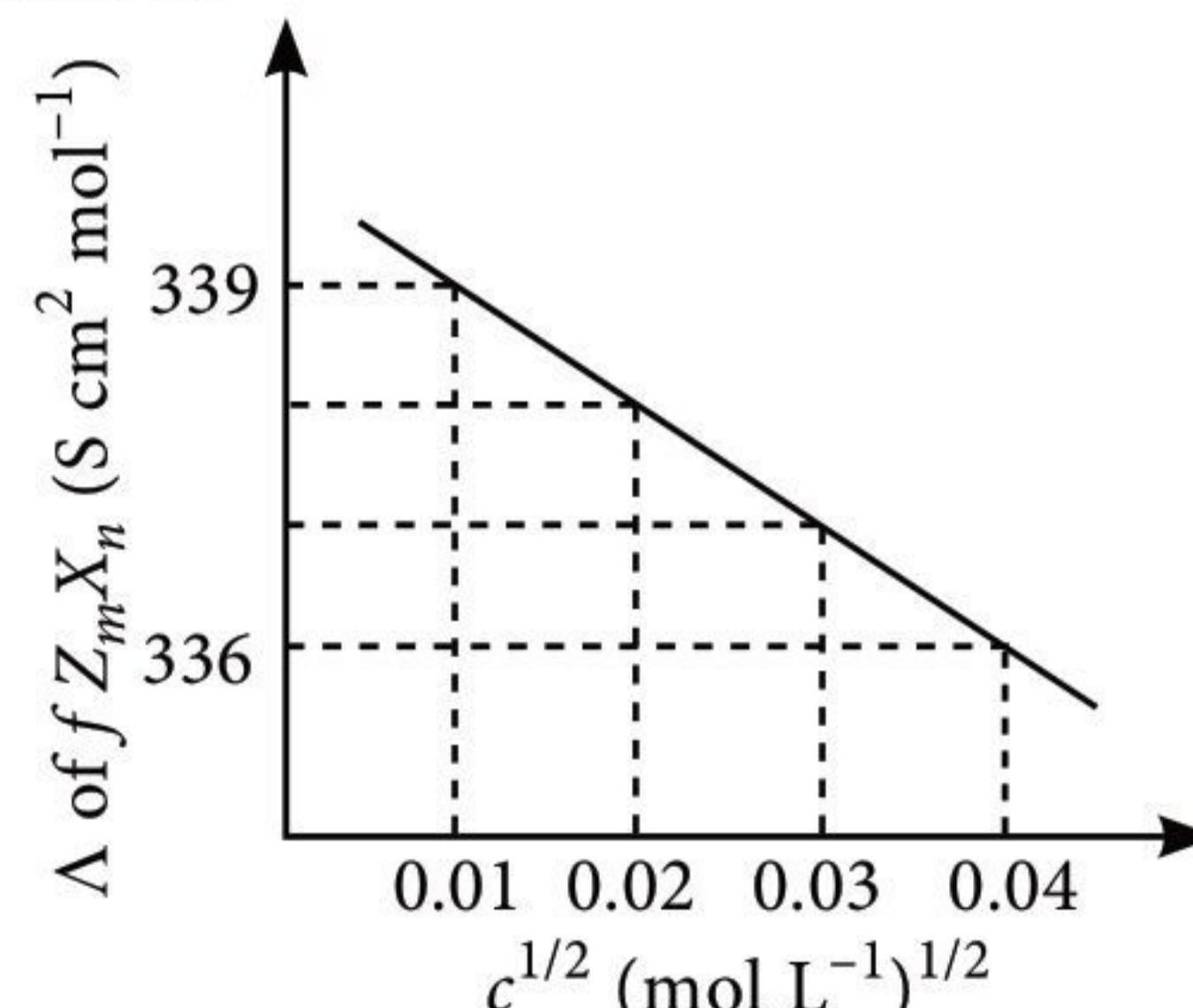
3. Consider the strong electrolytes  $Z_mX_n$ ,  $U_mY_p$  and  $V_mX_n$ . Limiting molar conductivity ( $\Lambda^\circ$ ) of  $U_mY_p$  and  $V_mX_n$  are 250 and 440  $\text{S cm}^2 \text{ mol}^{-1}$ , respectively. The value of  $(m + n + p)$  is \_\_\_\_\_.

Given :

Ion	$Z^{n+}$	$U^{p+}$	$V^{n+}$	$X^{m-}$	$Y^{m-}$
$\lambda^\circ (\text{S cm}^2 \text{ mol}^{-1})$	50.0	25.0	100.0	80.0	100.0

$\lambda^\circ$  is limiting molar conductivity of ions.

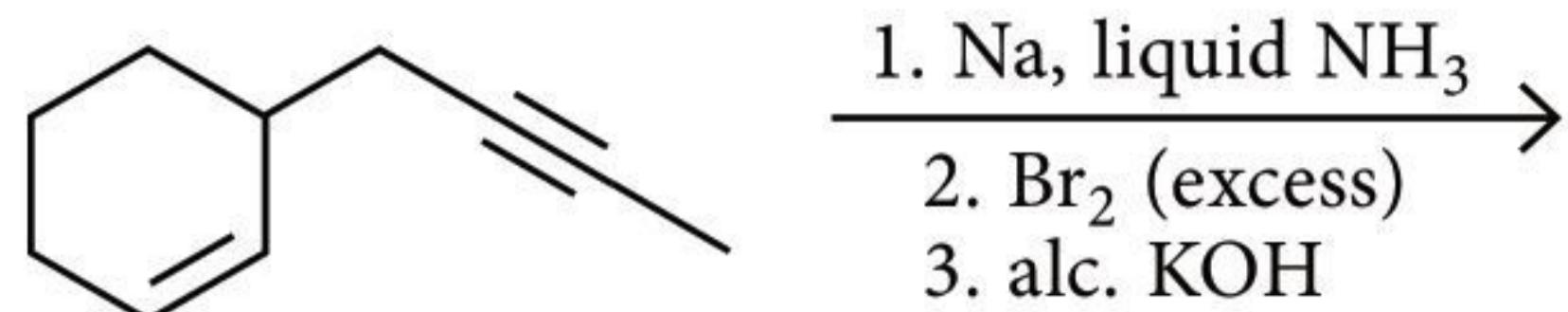
The plot of molar conductivity ( $\Lambda$ ) of  $Z_mX_n$  vs  $c^{1/2}$  is given below.



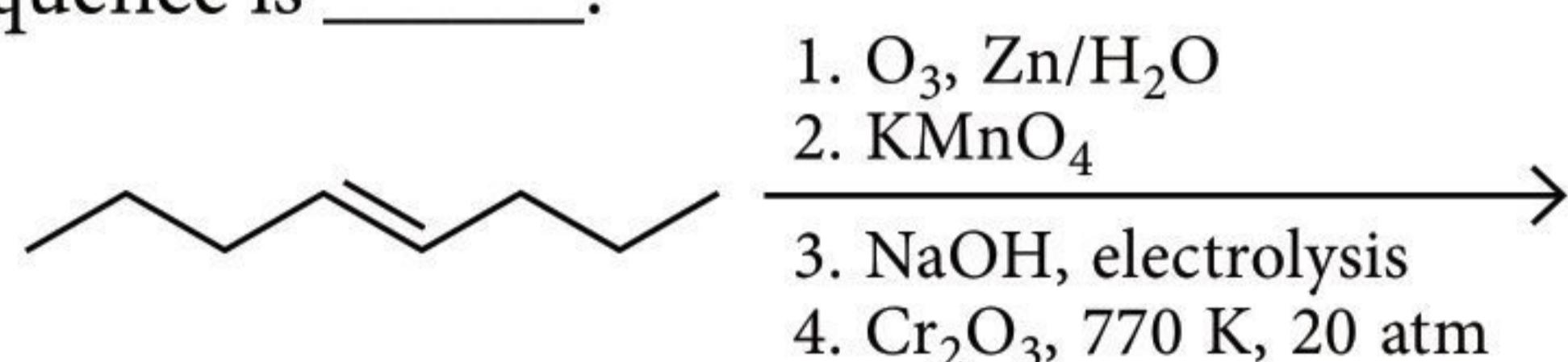
4. The reaction of Xe and  $\text{O}_2\text{F}_2$  gives a Xe compound P. The number of moles of HF produced by the complete hydrolysis of 1 mol of P is \_\_\_\_\_.

5. Thermal decomposition of  $\text{AgNO}_3$  produces two paramagnetic gases. The total number electrons present in the antibonding molecular orbitals of the gas that has the higher number of unpaired electrons is \_\_\_\_\_.

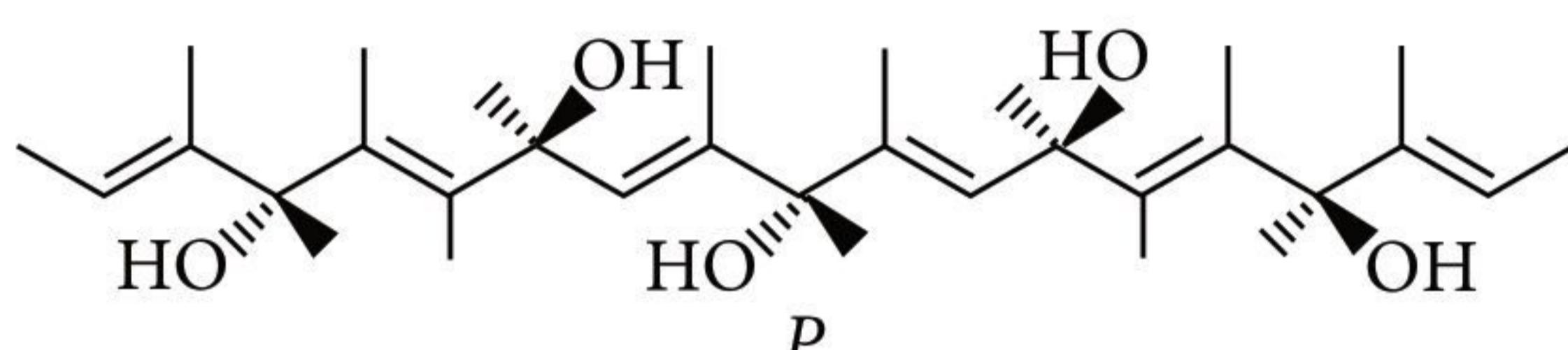
6. The number of isomeric tetraenes (NOT containing  $sp$ -hybridized carbon atoms) that can be formed from the following reaction sequence is \_\_\_\_\_.



7. The number of  $-\text{CH}_2-$  (methylene) groups in the product formed from the following reaction sequence is \_\_\_\_\_.



8. The total number of chiral molecules formed from one molecule of  $P$  on complete ozonolysis ( $\text{O}_3, \text{Zn}/\text{H}_2\text{O}$ ) is \_\_\_\_\_.



### SECTION 2 (MAXIMUM MARKS : 24)

- This section contains SIX (06) questions.**
- Each question has FOUR options (a), (b), (c) and (d). ONE OR MORE THAN ONE of these four option(s) is (are) correct answer(s).**
- For each question, choose the option(s) corresponding to (all) the correct answer(s).**
- Answer to each question will be evaluated according to the following marking scheme:**

**Full Marks : +4 ONLY if (all) the correct option(s) is(are) chosen;**

**Partial Marks : +3 If all the four options are correct but ONLY three options are chosen;**

**Partial Marks : +2 If three or more options are correct but ONLY two options are chosen, both of which are correct;**

**Partial Marks : +1 If two or more options are correct but ONLY one option is chosen and it is a correct options;**

**Zero Marks : 0 If unanswered;**

**Negative Marks : -2 In all other cases.**

9. To check the principle of multiple proportions, a series of pure binary compounds ( $P_mQ_n$ ) were analyzed and their composition is tabulated below. The correct option(s) is (are)

Compound	Weight % of $P$	Weight % of $Q$
1	50	50
2	44.4	55.6
3	40	60

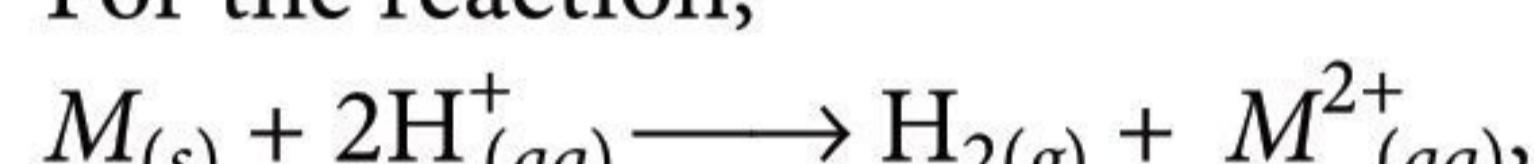
(a) If empirical formula of compound 3 is  $P_3Q_4$ , then the empirical formula of compound 2 is  $P_3Q_5$ .  
 (b) If empirical formula of compound 3 is  $P_3Q_2$  and atomic weight of element  $P$  is 20, then the atomic weight of  $Q$  is 45.  
 (c) If empirical formula of compound 2 is  $PQ$ , then the empirical formula of the compound 1 is  $P_5Q_4$ .  
 (d) If atomic weight of  $P$  and  $Q$  are 70 and 35, respectively, then the empirical formula of compound 1 is  $P_2Q$ .

10. The correct option(s) about entropy ( $S$ ) is(are)

[ $R$  = gas constant,  $F$  = Faraday constant,

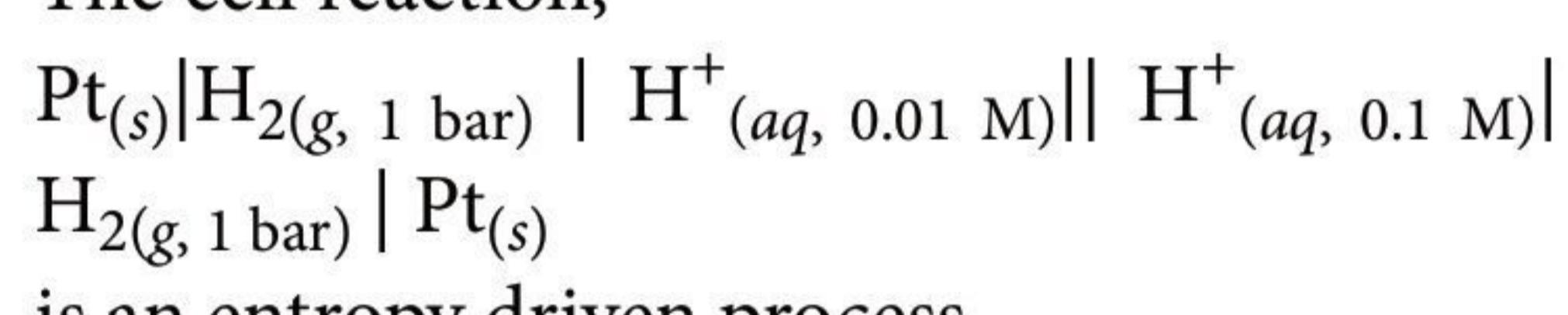
$T$  = Temperature]

(a) For the reaction,



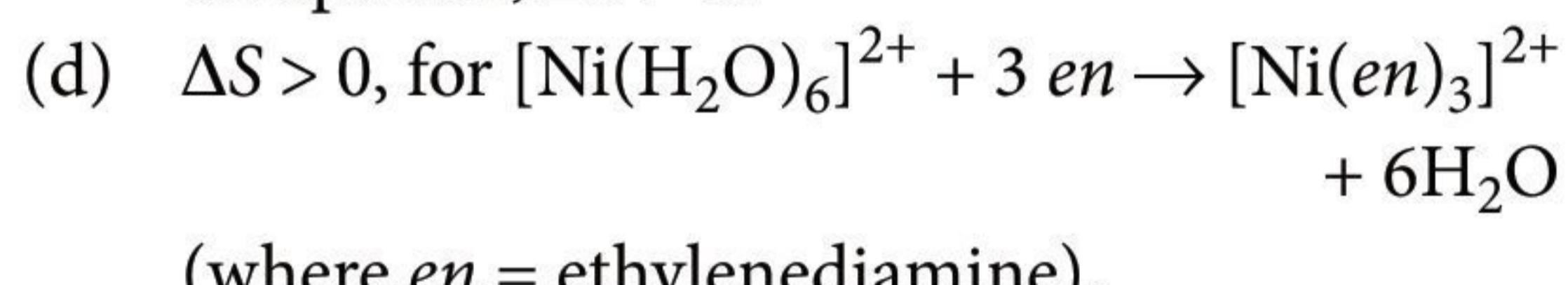
if  $\frac{dE_{\text{cell}}}{dT} = \frac{R}{F}$ , then the entropy change of the reaction is  $R$  (assume that entropy and internal energy changes are temperature independent).

(b) The cell reaction,



is an entropy driven process.

(c) For racemization of an optically active compound,  $\Delta S > 0$ .



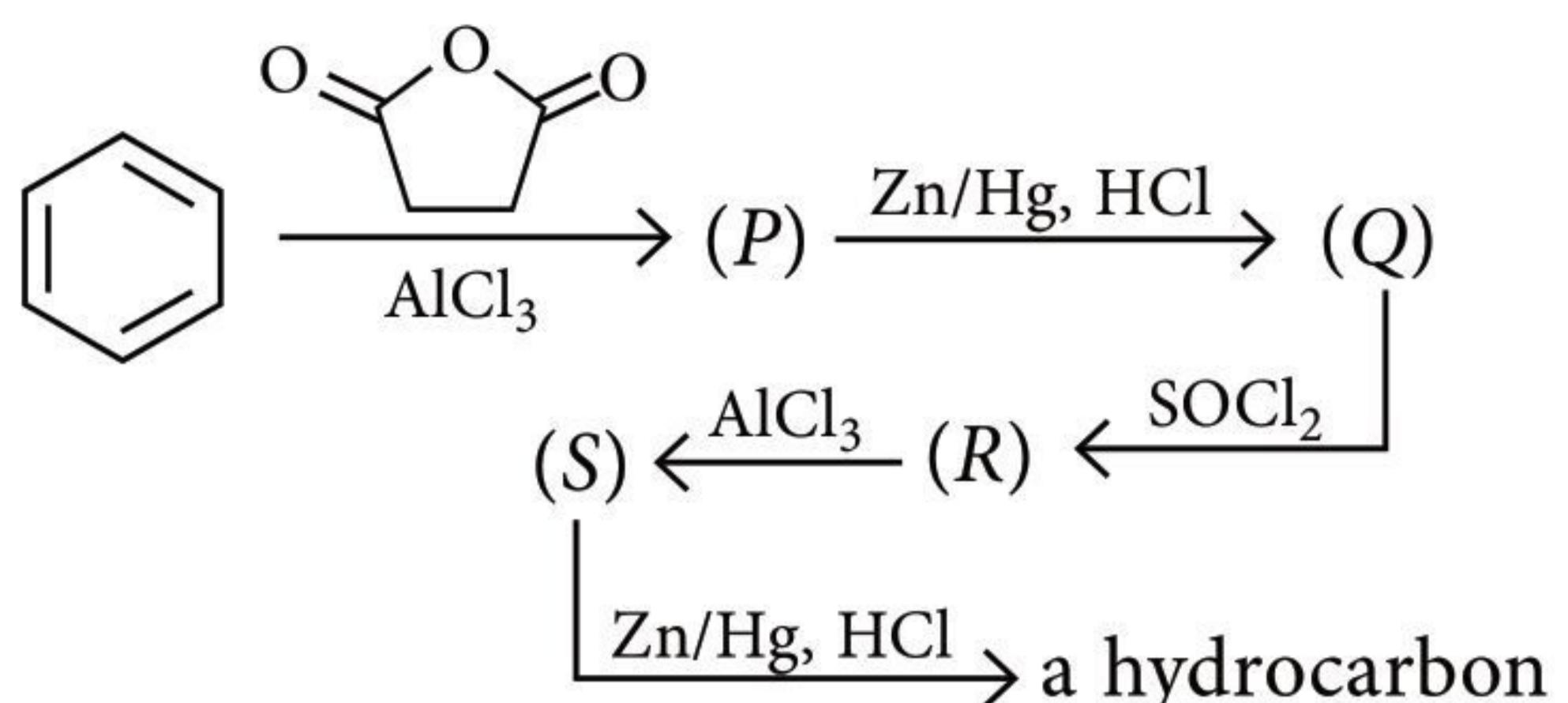
11. The compound(s) which react(s) with  $\text{NH}_3$  to give boron nitride (BN) is(are)

(a) B (b)  $\text{B}_2\text{H}_6$   
 (c)  $\text{B}_2\text{O}_3$  (d)  $\text{HBF}_4$

12. The correct option(s) related to the extraction of iron from its ore in the blast furnace operating in the temperature range 900 – 1500 K is (are)

(a) limestone is used to remove silicate impurity.  
 (b) pig iron obtained from blast furnace contains about 4% carbon.  
 (c) coke (C) converts  $\text{CO}_2$  to  $\text{CO}$ .  
 (d) exhaust gases consist of  $\text{NO}_2$  and  $\text{CO}$ .

13. Considering the following reaction sequence, the correct statement(s) is (are)



(a) Compounds *P* and *Q* are carboxylic acids.  
 (b) Compound *S* decolourizes bromine water.  
 (c) Compounds *P* and *S* react with hydroxylamine to give the corresponding oximes.  
 (d) Compound *R* reacts with dialkylcadmium to give the corresponding tertiary alcohol.

**14.** Among the following, the correct statement(s) about polymers is(are)  
 (a) the polymerization of chloroprene gives natural rubber.  
 (b) teflon is prepared from tetrafluoroethene by heating it with persulphate catalyst at high pressures.  
 (c) PVC are thermoplastic polymers.  
 (d) ethene at 350-570 K temperature and 1000-2000 atm pressure in the presence of a peroxide initiator yields high density polythene.

### SECTION 3 (MAXIMUM MARKS : 12)

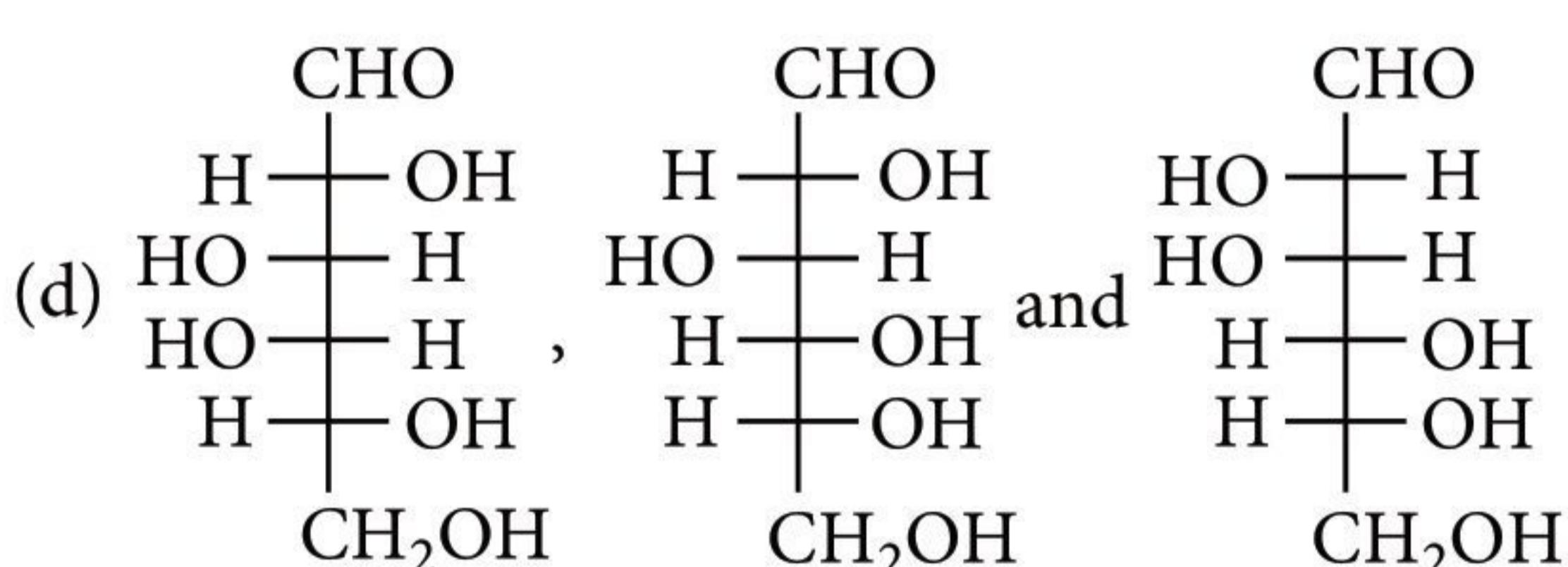
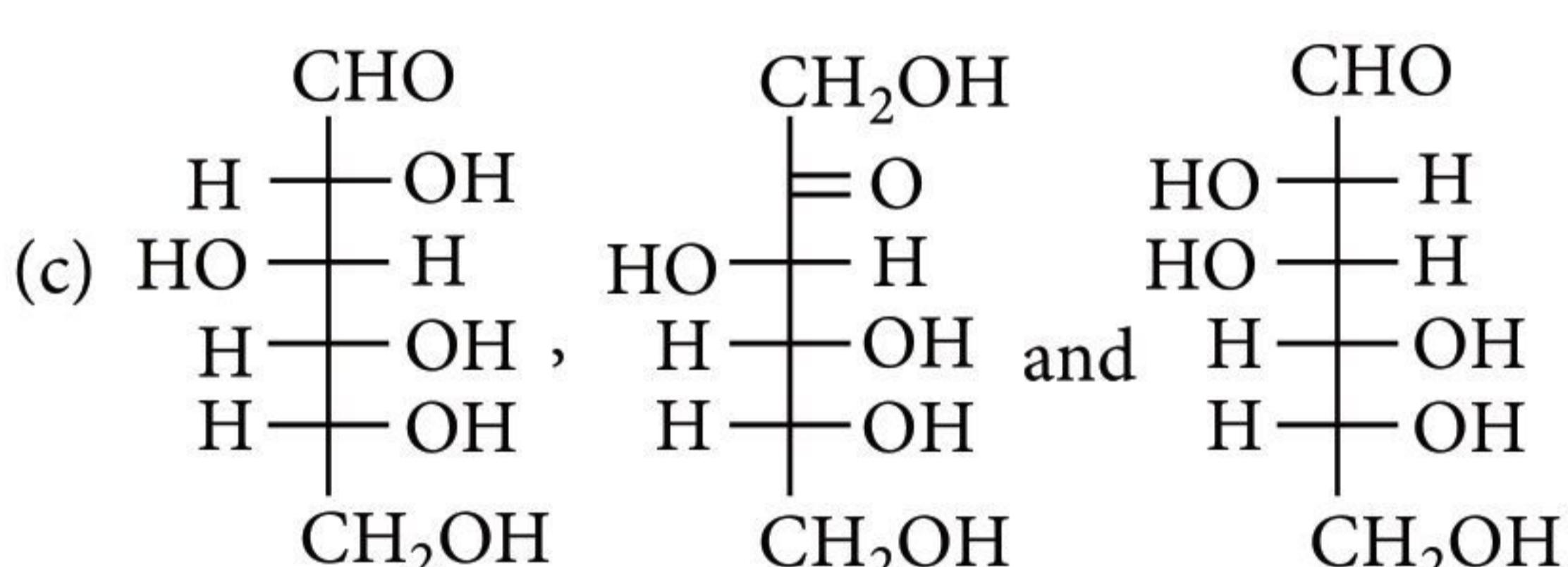
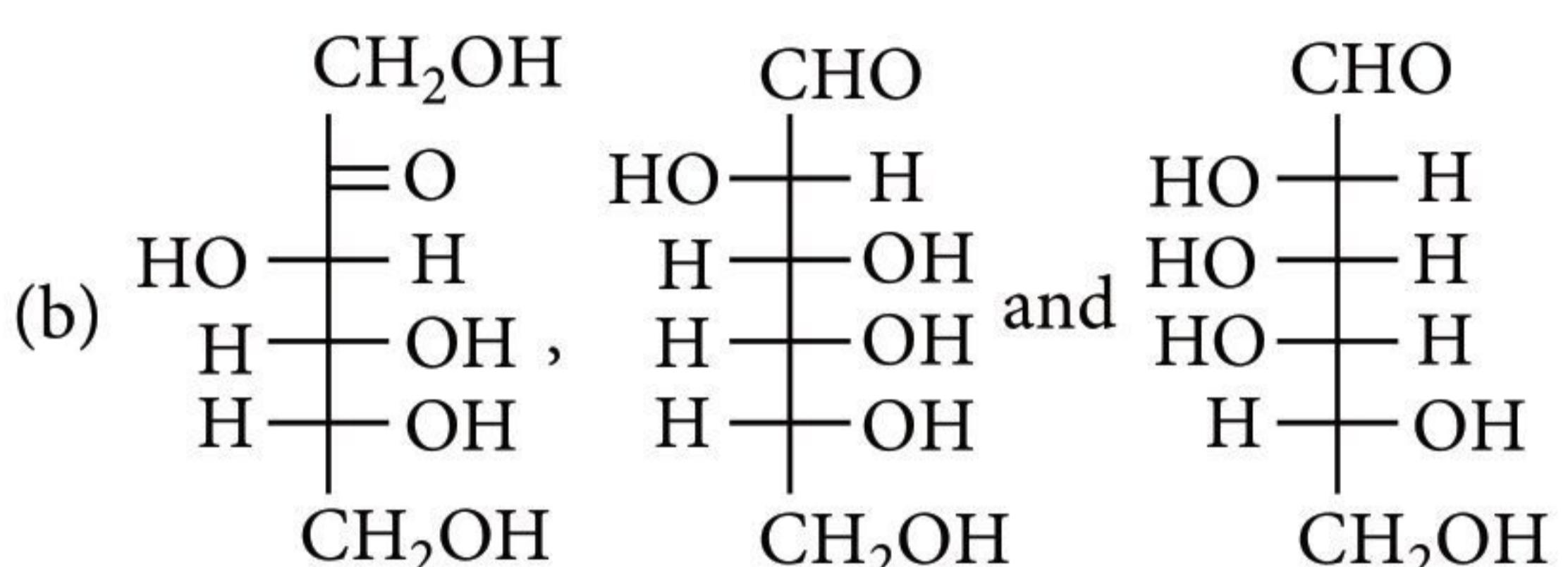
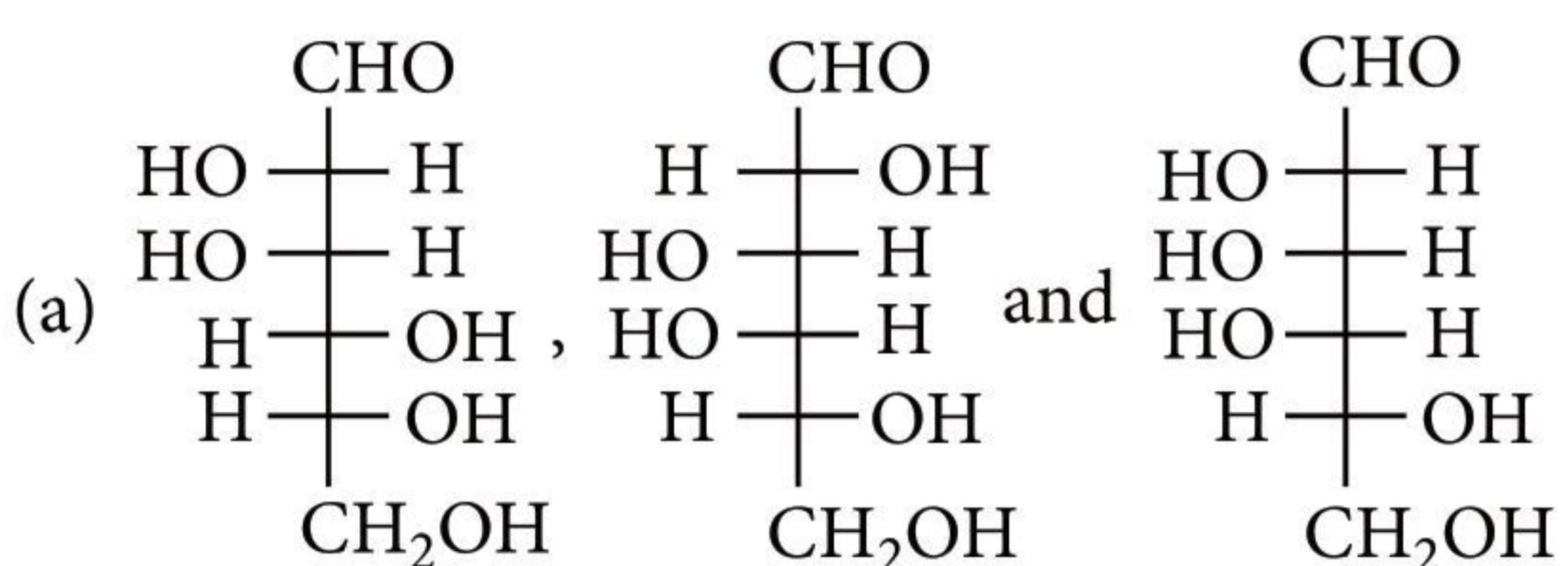
- This section contains FOUR (04) questions.*
- Each question has FOUR options (a), (b), (c) and (d). ONLY ONE of these four options is the correct answer.*
- For each question, choose the option corresponding to the correct answer.*
- Answer to each question will be evaluated according to the following marking scheme:*  
*Full Marks : +3 If ONLY the correct option is chosen;*  
*Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);*  
*Negative Marks : -1 In all other cases.*

**15.** Atom *X* occupies the fcc lattice sites as well as alternate tetrahedral voids of the same lattice. The packing efficiency (in %) of the resultant solid is closest to  
 (a) 25 (b) 35  
 (c) 55 (d) 75

**16.** The reaction of  $\text{HClO}_3$  with  $\text{HCl}$  gives a paramagnetic gas, which upon reaction with  $\text{O}_3$  produces  
 (a)  $\text{Cl}_2\text{O}$  (b)  $\text{ClO}_2$   
 (c)  $\text{Cl}_2\text{O}_6$  (d)  $\text{Cl}_2\text{O}_7$

**17.** The reaction of  $\text{Pb}(\text{NO}_3)_2$  and  $\text{NaCl}$  in water produces a precipitate that dissolves upon the addition of  $\text{HCl}$  of appropriate concentration. The dissolution of the precipitate is due to the formation of  
 (a)  $\text{PbCl}_2$  (b)  $\text{PbCl}_4$   
 (c)  $[\text{PbCl}_4]^{2-}$  (d)  $[\text{PbCl}_6]^{2-}$

**18.** Treatment of *D*-glucose with aqueous  $\text{NaOH}$  results in a mixture of monosaccharides, which are

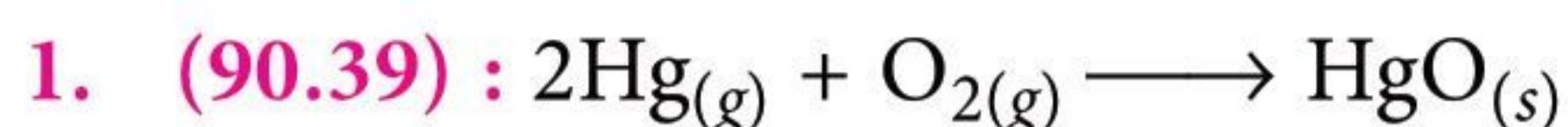


### MONTHLY TEST DRIVE CLASS XI ANSWER KEY

1. (a)	2. (c)	3. (b)	4. (b)
6. (b)	7. (d)	8. (c)	9. (a)
11. (b)	12. (d)	13. (c)	14. (b)
16. (c)	17. (b)	18. (b)	19. (d)
21. (a,b)	22. (a,b,d)	23. (c,d)	24. (141)
26. (166)	27. (b)	28. (d)	29. (c)
			30. (b)

## SOLUTIONS

### PAPER - I



$$\Delta T = (312.8 - 298) \text{ K} = 14.8 \text{ K}$$

$C_v$  = heat capacity of bomb calorimeter = 20.00 kJ K<sup>-1</sup>

$\Delta_f H^\circ$  = enthalpy of formation of  $\text{Hg}_{(g)}$  = 61.32 kJ mol<sup>-1</sup>

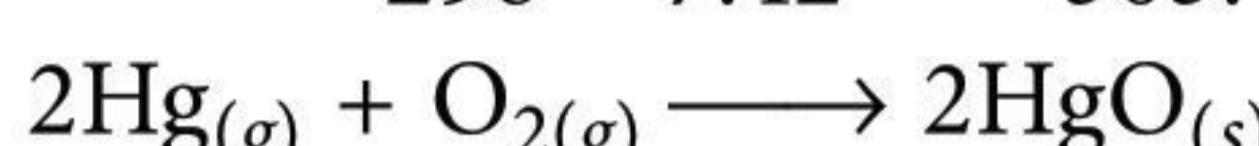
$$q = C_v \times \Delta T = 20 \times 14.8 \text{ kJ} = 296 \text{ kJ}$$

Heat released during combustion = -296 kJ

$$\Delta n_g = 0 - 3 = -3$$

$$\Delta H^\circ = \Delta U^\circ + \Delta n_g RT$$

$$\Delta H^\circ = -296 \text{ kJ} + (-3) \times 8.3 \times 298 \times 10^{-3} \text{ kJ} = -296 - 7.42 = -303.42 \text{ kJ}$$



$$\Delta H^\circ = 2\Delta_f H^\circ_{\text{HgO}_{(s)}} - 2 \times \Delta_f H^\circ_{\text{Hg}_{(g)}} - \Delta_f H^\circ_{\text{O}_{2(g)}}$$

$$-303.42 = \Delta_f H^\circ_{\text{HgO}_{(s)}} - 2 \times 61.32 - 0$$

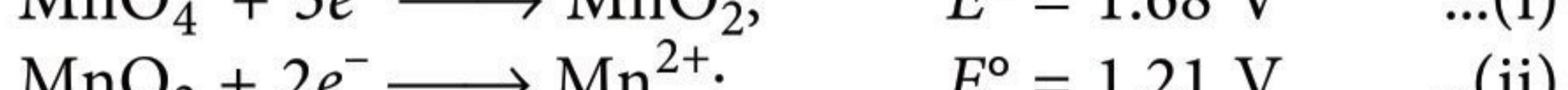
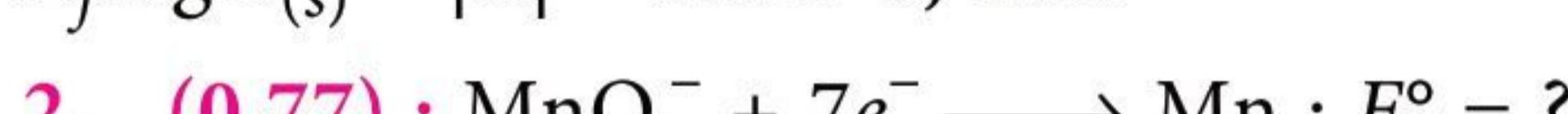
$$-303.42 + 122.64 = 2\Delta_f H^\circ_{\text{HgO}_{(s)}}$$

$$2\Delta_f H^\circ_{\text{HgO}_{(s)}} = -180.78 \text{ kJ}$$

Standard enthalpy of formation of  $\text{HgO}_{(s)}$

$$= \frac{\Delta_f H^\circ_{\text{HgO}_{(s)}}}{2} = \frac{-180.78}{2} = -90.39 \text{ kJ mol}^{-1}$$

$$\Delta_f H^\circ_{\text{HgO}_{(s)}} = |X| = 90.39 \text{ kJ mol}^{-1}$$



Add equation (i), (ii) & (iii) to get desired equation.

$$\text{So, } \Delta G = \Delta G_1 + \Delta G_2 + \Delta G_3$$

$$-nFE^\circ = -3F \times 1.68 \text{ V} + (-2 \times F \times 1.21 \text{ V}) + [-2 \times F \times (-1.03 \text{ V})]$$

$$-7FE^\circ = -5.04 F - 2.42 F + 2.06 F$$

$$-7E^\circ = -5.4 \text{ V}$$

$$E^\circ = \frac{5.4}{7} \text{ V} = 0.7714 \text{ V} \approx 0.77 \text{ V}$$

3. (10.02) :  $\text{H}_2\text{CO}_3$  reacts with  $\text{NaOH}$  to form  $\text{NaHCO}_3$  and water.



$$0.01 \text{ mol} \quad 0.01 \text{ mol} \quad 0.01 \text{ mol}$$

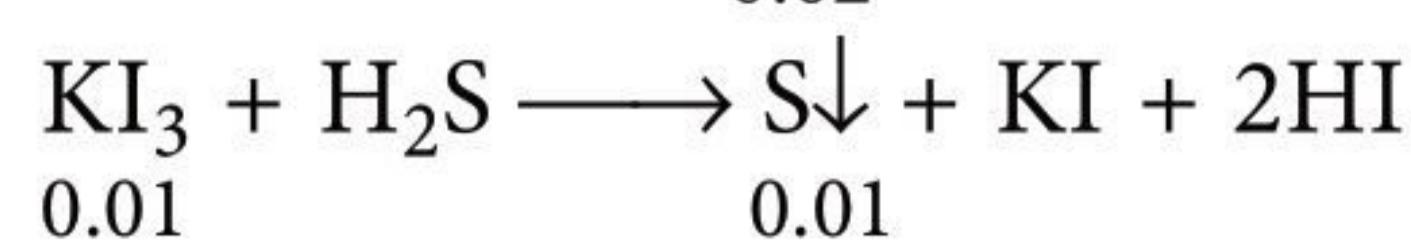
So, we have 0.02 mol of  $\text{NaHCO}_3$  and 0.01 mol of  $\text{Na}_2\text{CO}_3$  in the final mixture.

The combination of  $\text{NaHCO}_3$  and  $\text{Na}_2\text{CO}_3$  forms a acidic buffer.

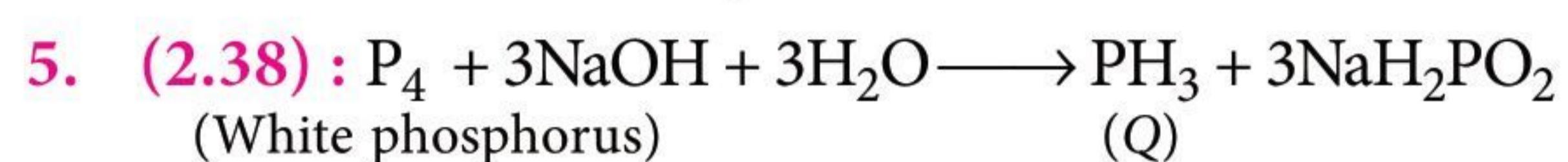
$$\text{pH} = \text{p}K_{a_2} + \log \frac{[\text{Salt}]}{[\text{Acid}]} = 10.32 + \log \left( \frac{0.01/0.1}{0.02/0.1} \right)$$

$$= 10.32 - \log 2 = 10.32 - 0.30$$

$$\text{pH} = 10.02$$

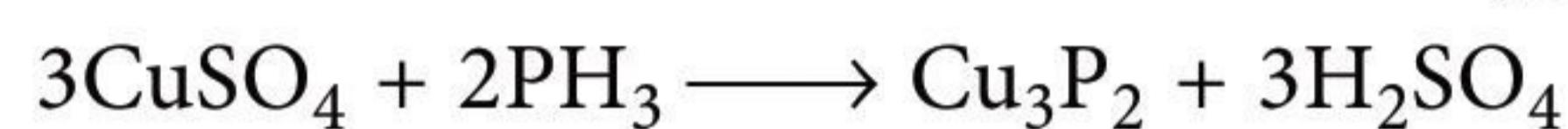


$$n_s = 0.01 \text{ mol} \times \text{molecular weight of sulphur} = 32 \times 0.01 = 0.32 \text{ g}$$



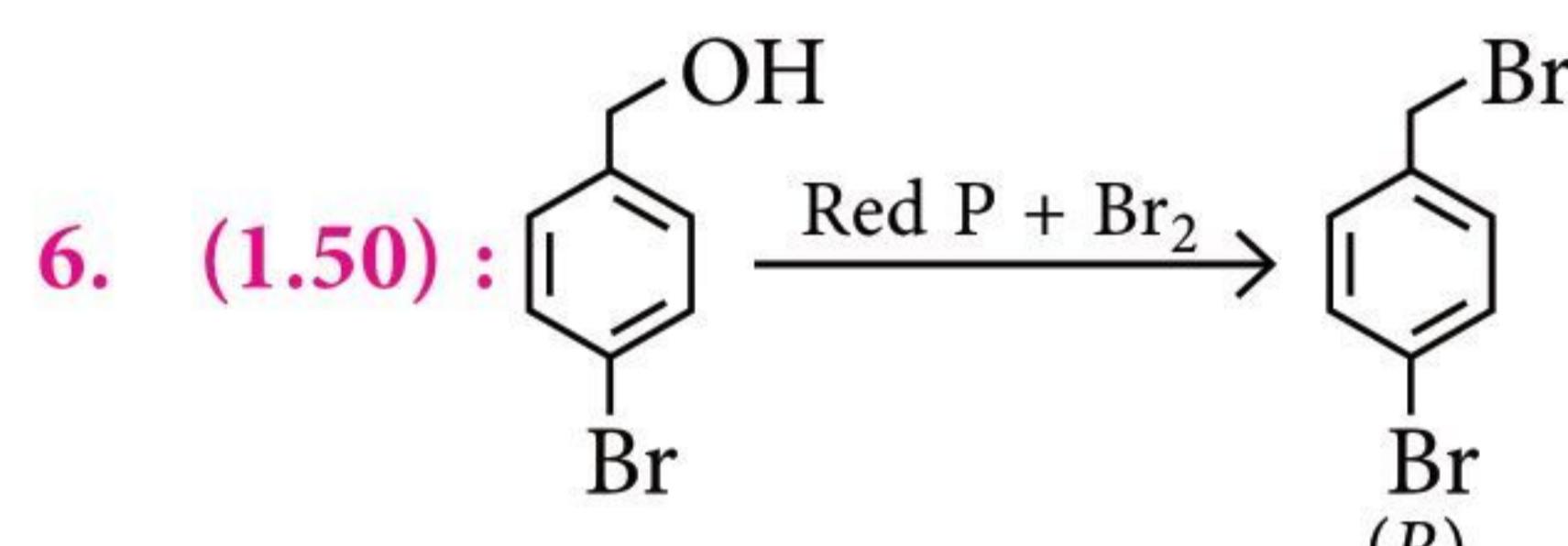
124 g of white phosphorus gives 34 g of phosphine gas ( $\text{PH}_3$ ).

$$1.24 \text{ g of white phosphorus gives } \left( \frac{34}{124} \times 1.24 \right) \text{ g of } \text{PH}_3 \text{ i.e., } 0.34 \text{ g of } \text{PH}_3$$



68 g of  $\text{PH}_3$  required 477 g of  $\text{CuSO}_4$ .

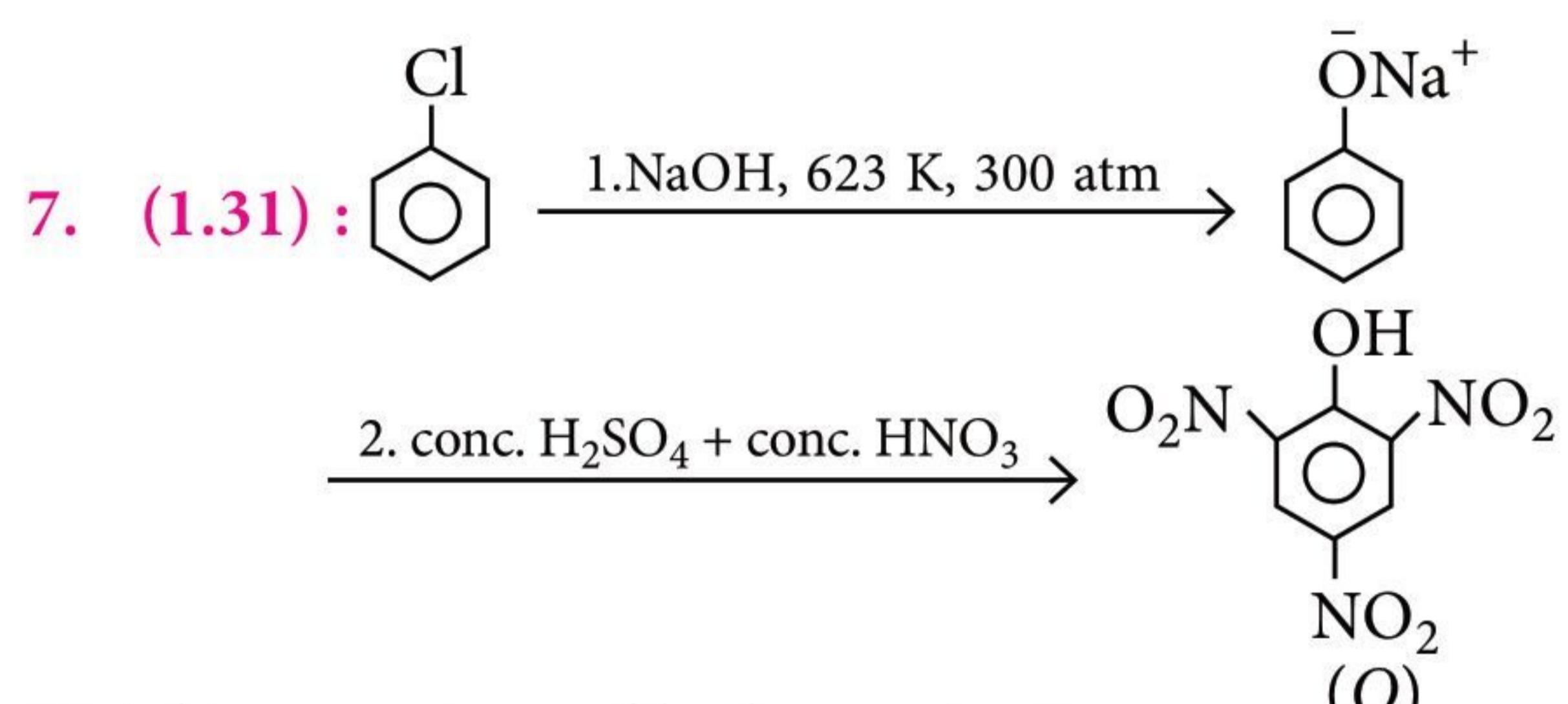
$$\text{So, } 0.34 \text{ g of } \text{PH}_3 \text{ required } \left( \frac{477}{68} \times 0.34 \right) \text{ g of } \text{CuSO}_4. \text{ i.e., } 2.38 \text{ g of } \text{CuSO}_4$$



1 mol of 'R' has 2 mol of Br.

$$\text{So, } \frac{1}{250} \text{ mol of } R \text{ contains } \frac{2}{250} \text{ mol of } \text{AgBr}.$$

$$\text{Hence, } \frac{2}{250} = \frac{w}{188} \Rightarrow w = 1.50 \text{ g}$$



Weight percentage of hydrogen in Q

$$= \frac{3}{(3 + 72 + 42 + 112)} \times 100 = 1.31\%$$

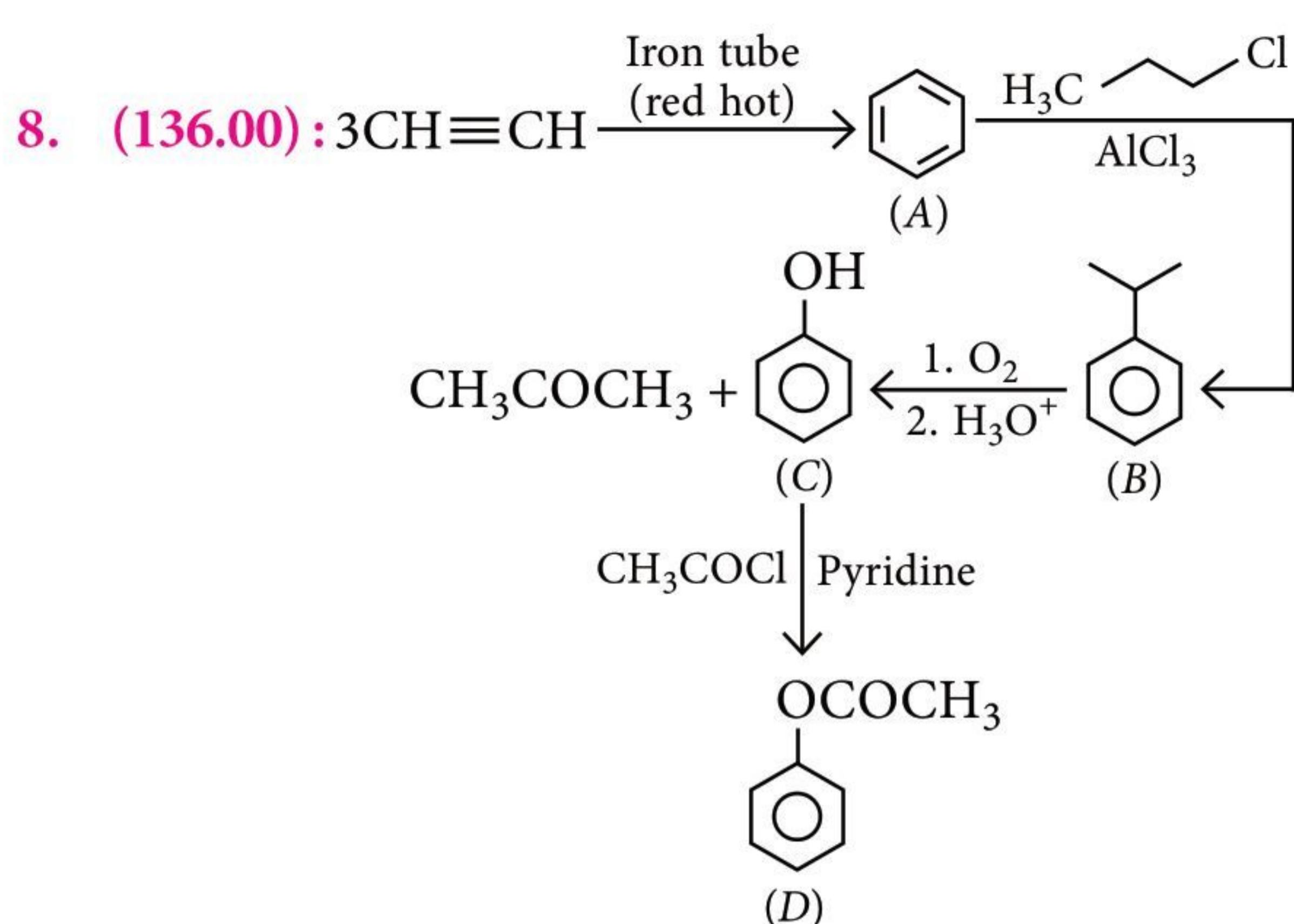


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3 moles of acetylene forms 1 mole of benzene.  
15 moles of acetylene can form 5 moles of benzene.  
Yield of 'A' is 80%.

$$\text{So, } 80\% \text{ of 5 moles} = \frac{80}{100} \times 5 = 4 \text{ moles}$$

Hence, the formation of 4 moles of benzene takes place.  
⇒ Yield of 'B' is 50%.

So, 4 moles of 'A' gives only 2 moles of 'B'.

⇒ Yield of 'C' is 50%

So, 2 moles 'B' gives only 1 mole of 'C'.

⇒ Yield of 'D' is 100%.

So, 1 mole of 'C' gives 1 mole of 'D'.

Thus, amount of 1 mole of 'D' is 136 g.

### 9. (a, d)

10. (a, d) : Enthalpy change during physisorption is in the range of (20 – 40)  $\text{kJ mol}^{-1}$ .

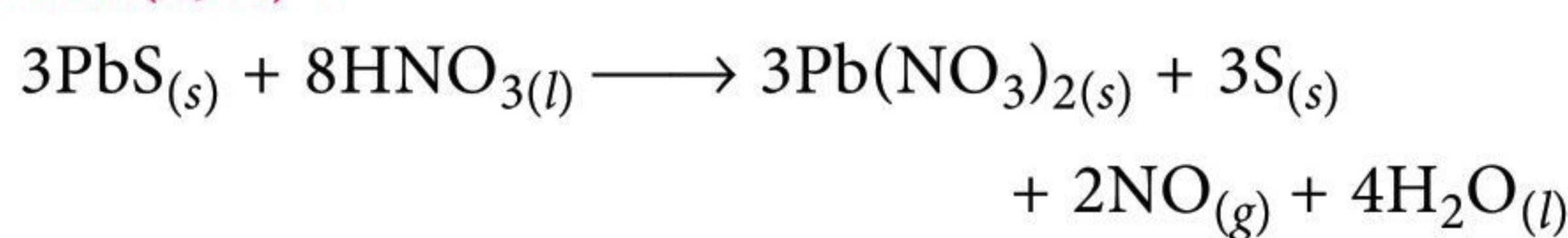
Chemisorption results into unimolecular layer while physisorption results into multimolecular layer.

Chemisorption is an exothermic process that increases with increase of temperature.

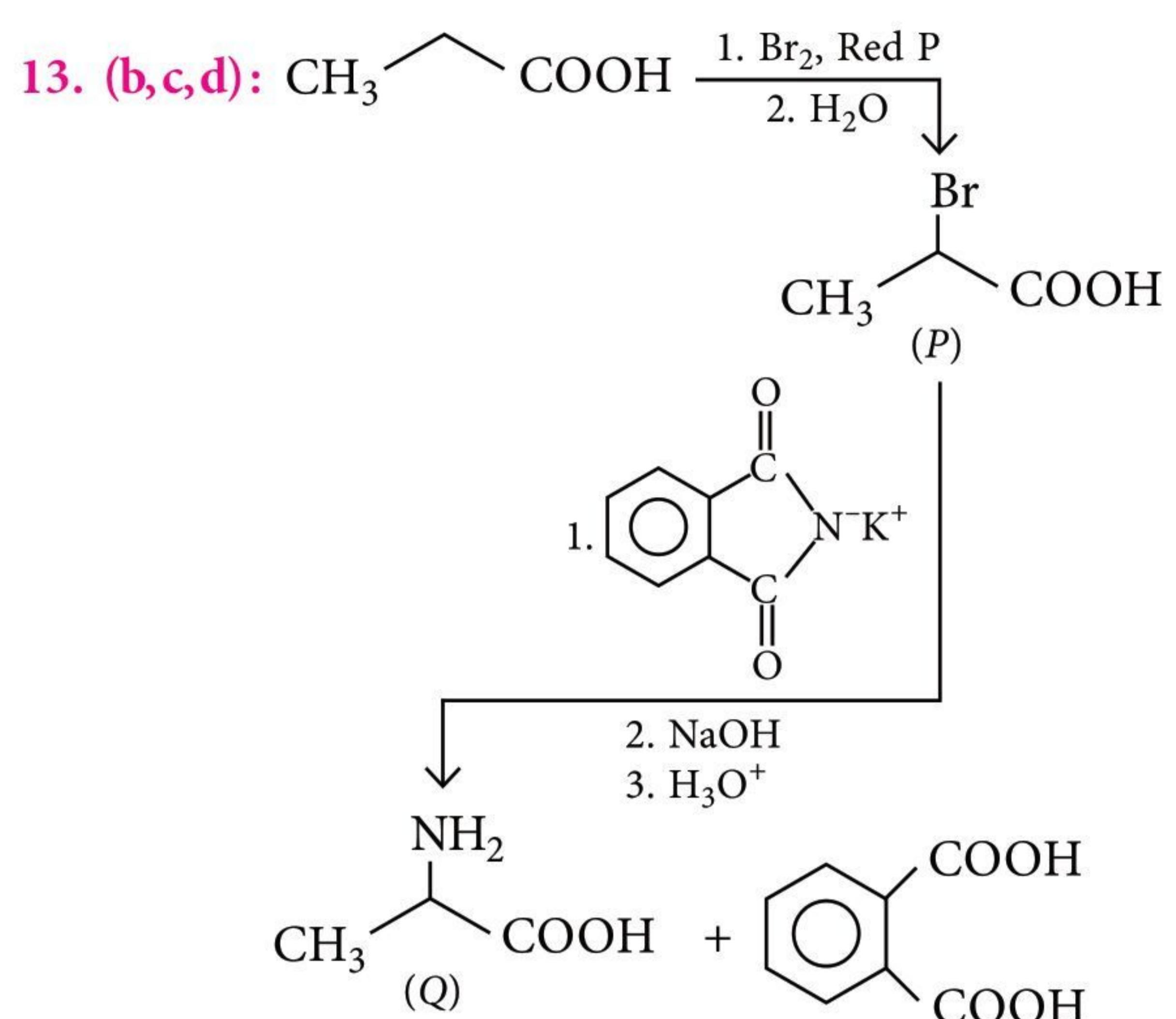
Low temperature is favourable for physisorption.

11. (b,c,d) : The reaction of  $\text{Al}_2\text{O}_3$  with C takes place below  $2500^\circ\text{C}$ .

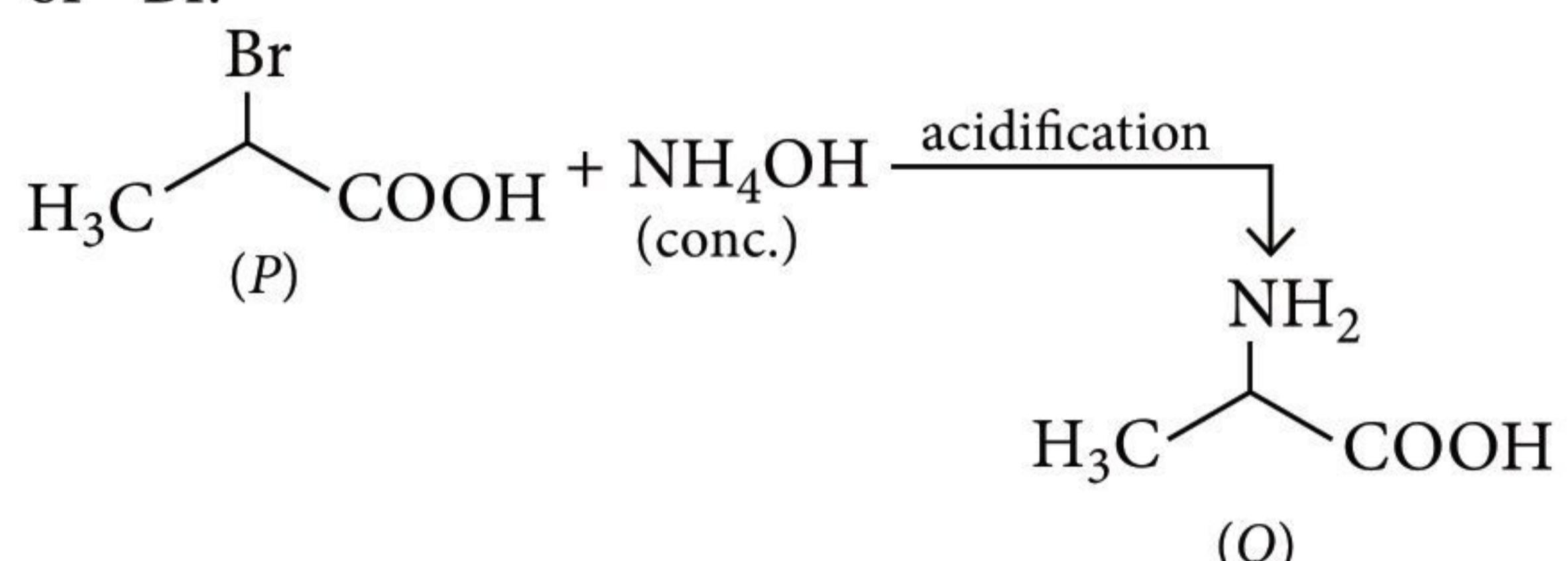
12. (a, d) : Galena is  $\text{PbS}$ .



'NO' is the gas that is produced during reaction which is colourless and paramagnetic due to the presence of an unpaired electron on 'N'. It is neutral oxide. It has linear geometry.



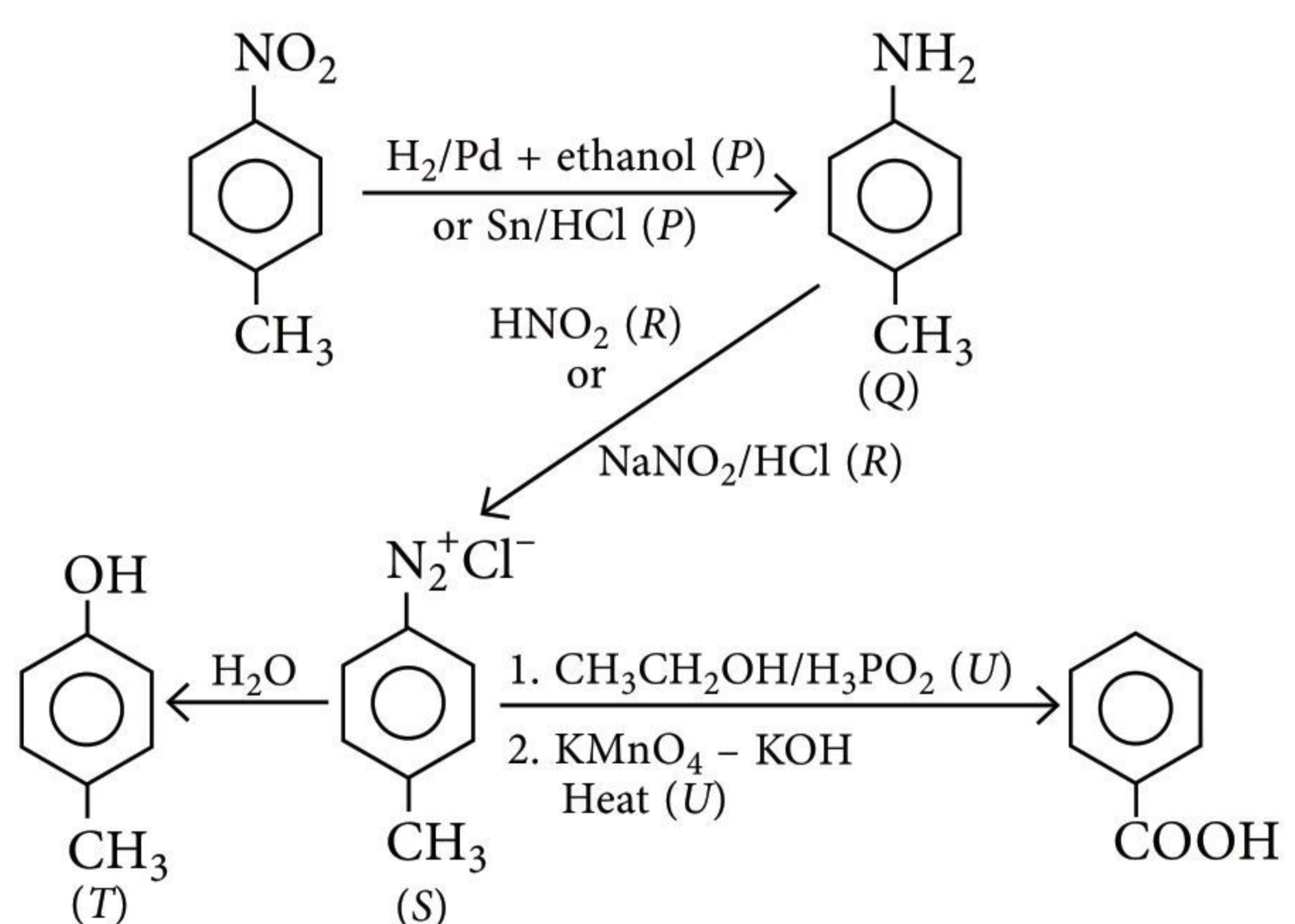
P is more acidic than  $\text{CH}_3\text{CH}_2\text{COOH}$  due to  $-I$  effect of  $-Br$ .



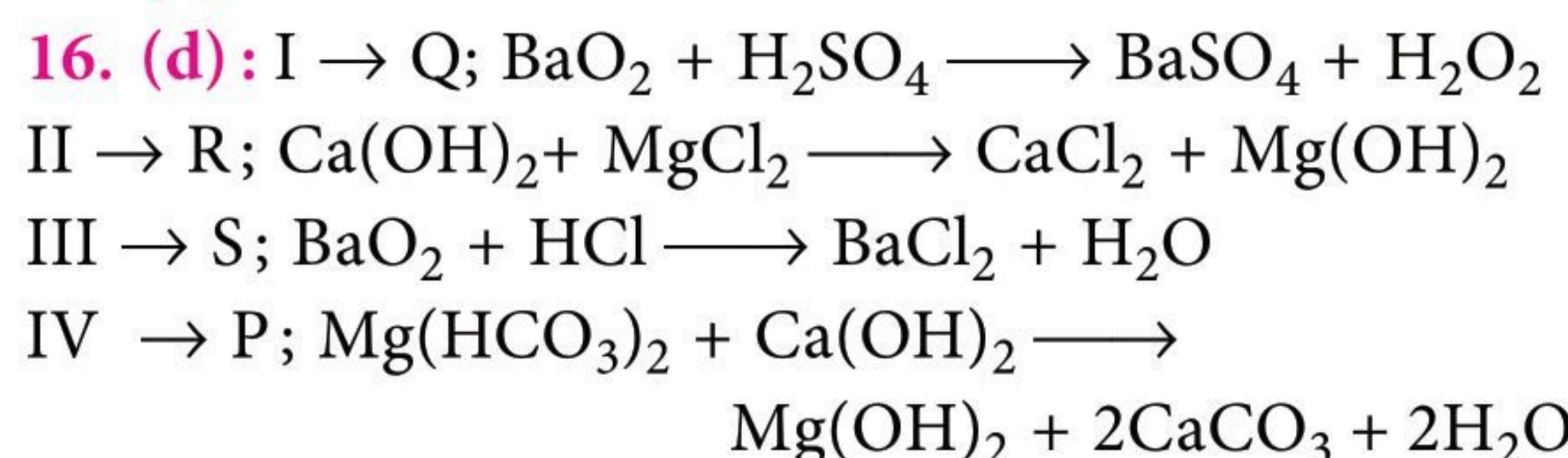
'Q' liberates  $\text{N}_2$  gas on treatment with  $\text{HNO}_2$ .

$\text{NaBH}_4$  does not reduce  $-COOH$  to  $-CH_2OH$ .

### 14. (a, b, c) :

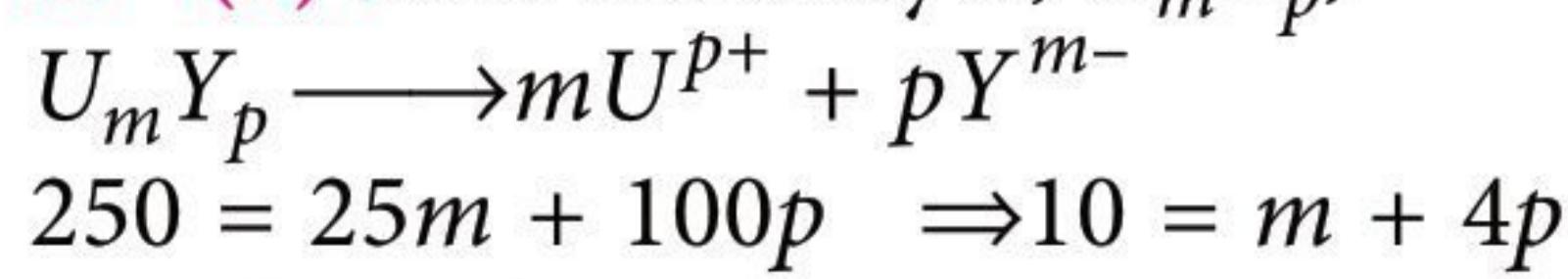


### 15. (a)

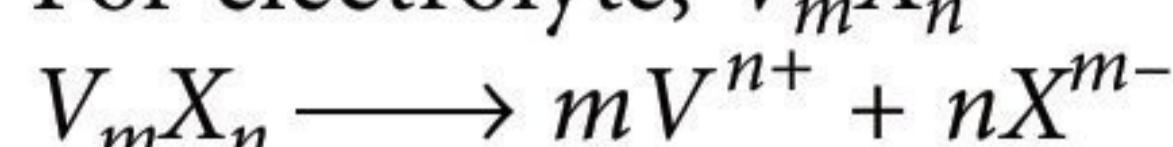




3. (7) : For electrolyte,  $U_m Y_p$ ,



For electrolyte,  $V_m X_n$



$$440 = m \times 100 + n \times 80 ; 22 = 5m + 4n$$

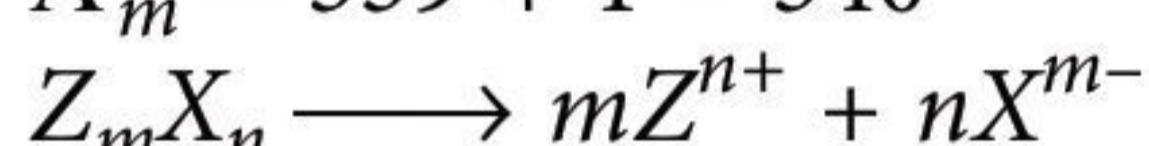
From graph, for electrolyte  $Z_m X_n$

$$\Lambda_m = -Ac^{1/2} + \Lambda_m^{\circ}$$

$$\therefore \text{Slope} (-A) = \frac{y_2 - y_1}{x_2 - x_1} = \frac{339 - 336}{0.01 - 0.04} = -\frac{3}{0.03} = -100$$

$$\therefore 339 = -100 \times 0.01 + \Lambda_m^{\circ}$$

$$\Lambda_m^{\circ} = 339 + 1 = 340$$

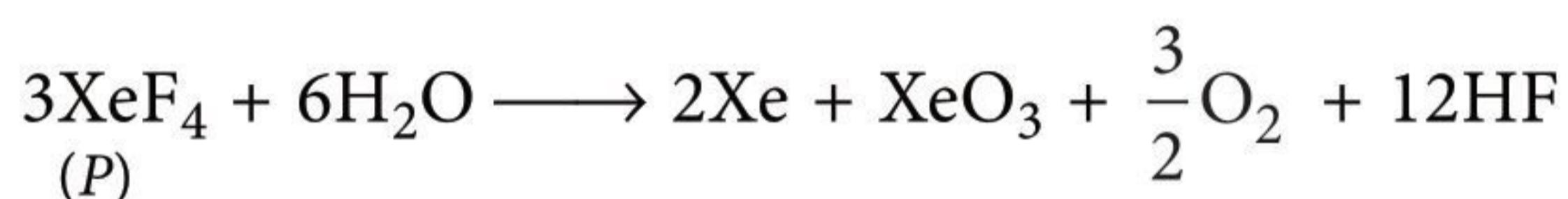
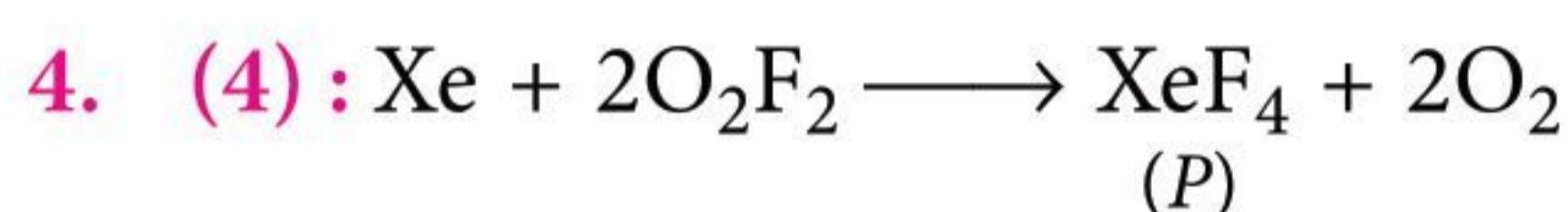


$$340 = m \times 50 + n \times 80 ; 34 = 5m + 8n$$

On solving equation (i), (ii) and (iii), we get

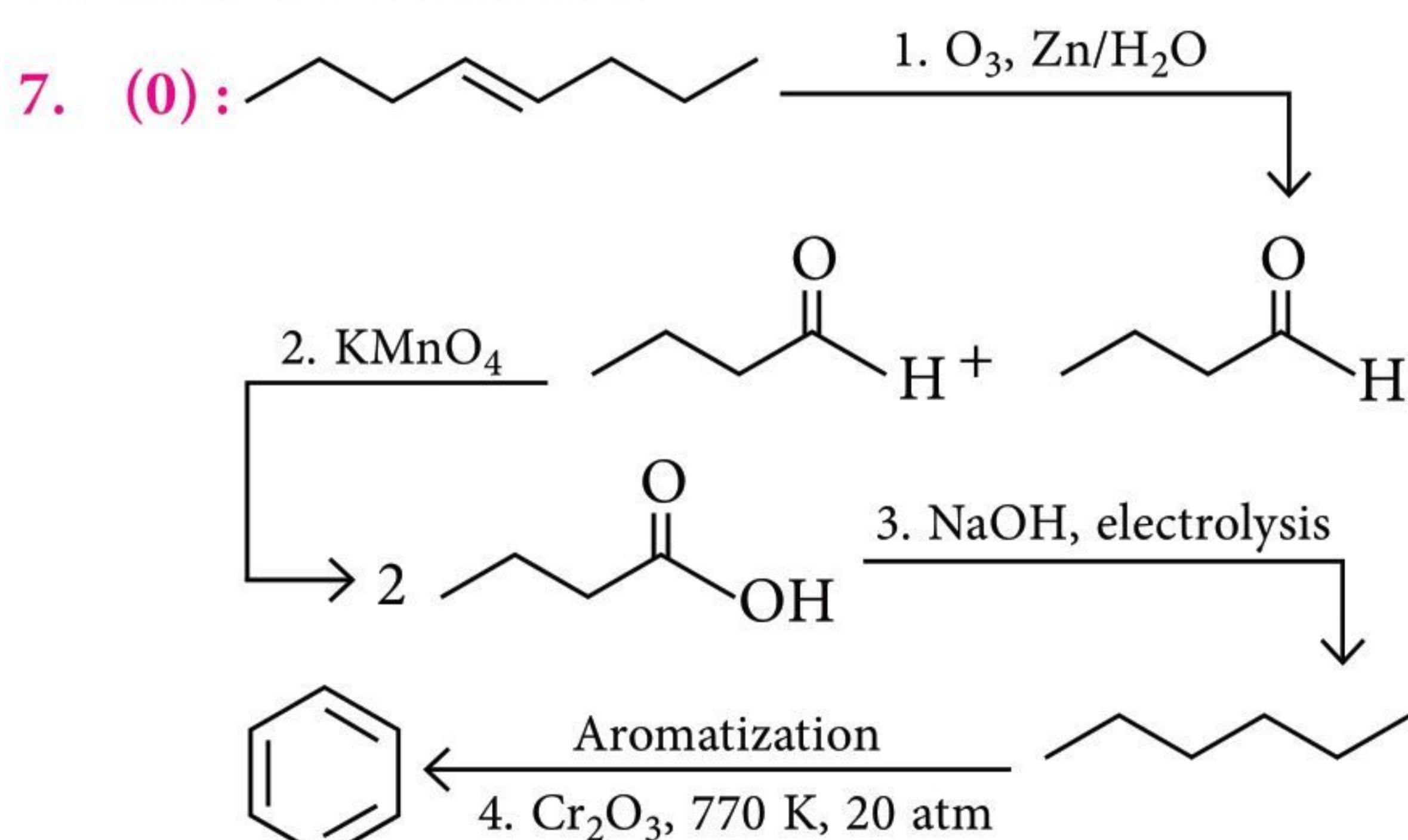
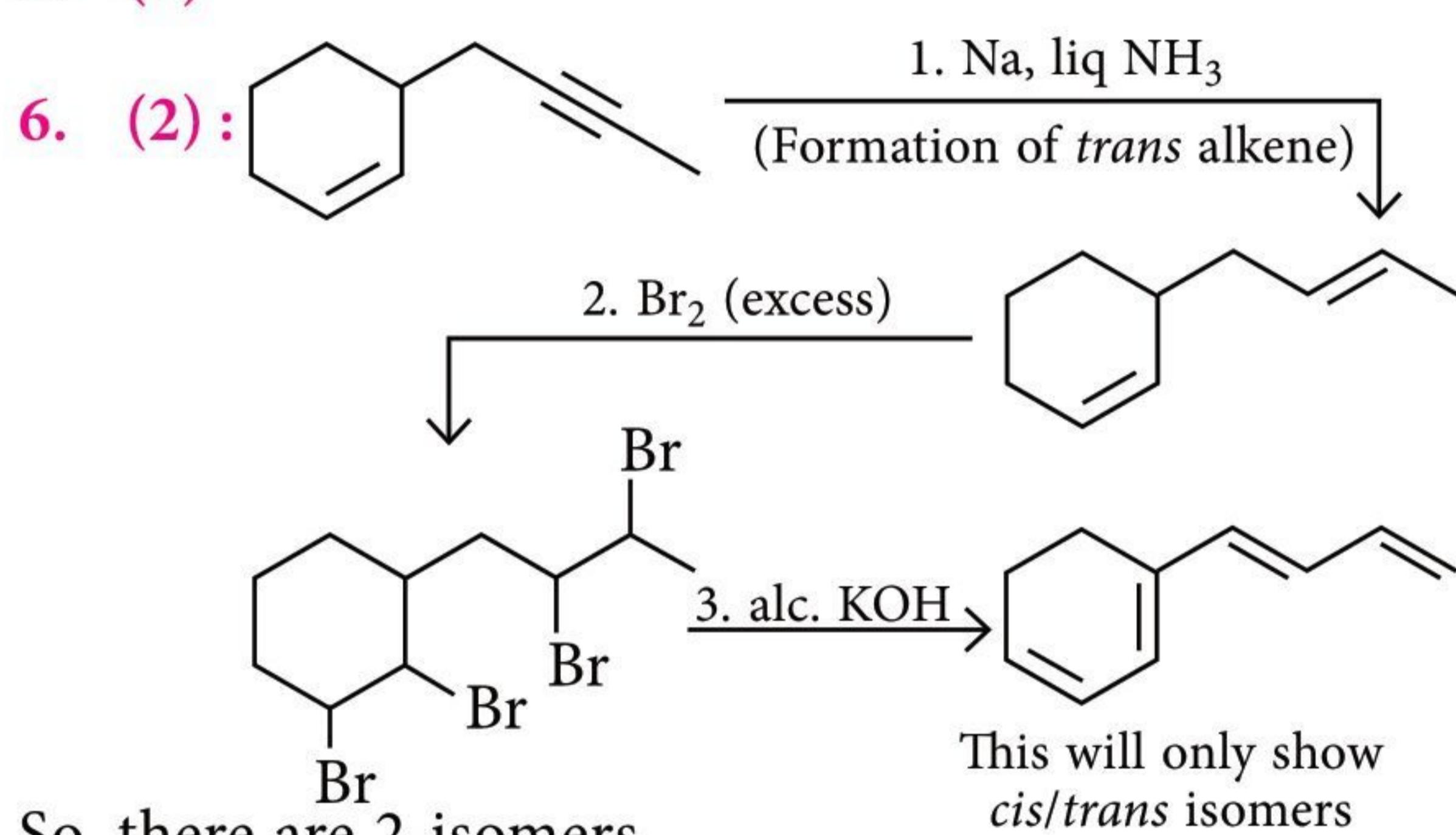
$$m = 2, n = 3, p = 2$$

$$\therefore \text{The value of } (m + n + p) = 2 + 3 + 2 = 7$$



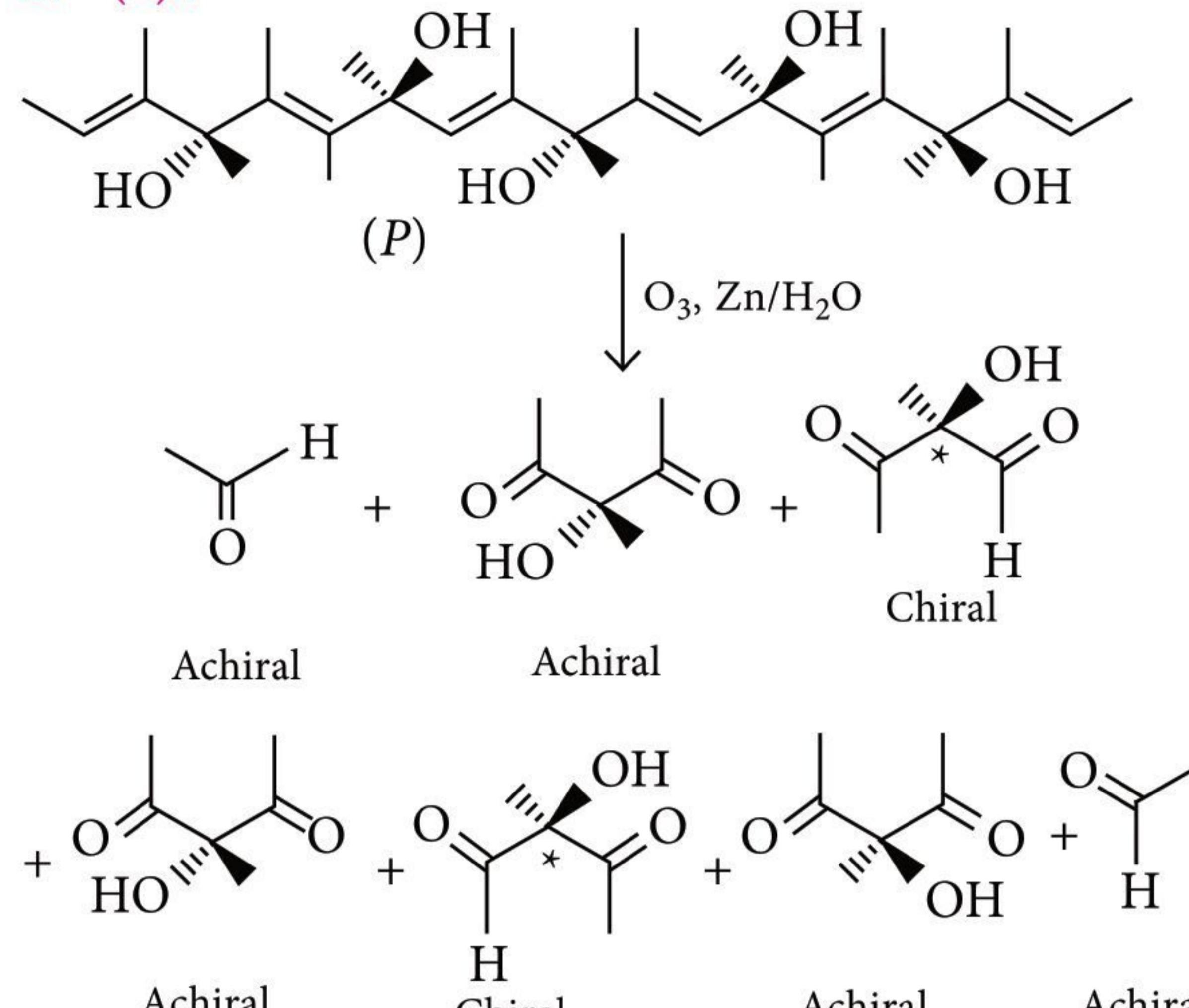
The number of moles of HF given by hydrolysis of 1 mol of  $\text{XeF}_4$  is 4.

5. (6)



As there is formation of benzene as the final product. Hence, the number of  $-\text{CH}_2-$  group present is zero.

8. (2) :



So, there is formation of 2 chiral molecules.

9. (b, c)

10. (b, c, d) :  $\Delta G = \Delta H - T\Delta S$

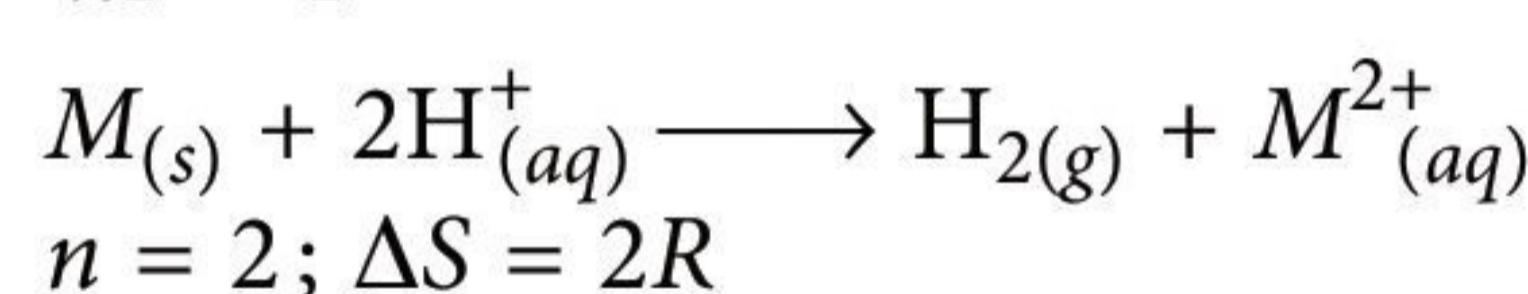
$$\Delta S = \frac{d(\Delta G)}{dt} \text{ at constant pressure}$$

$$\text{So, } \Delta S = nF \frac{dE}{dt}$$

$$\frac{dE}{dt} = \frac{\Delta S}{nF} \quad \text{...(i)} ; \quad \frac{dE}{dt} = \frac{R}{F} \quad \text{(Given)} \quad \text{...(ii)}$$

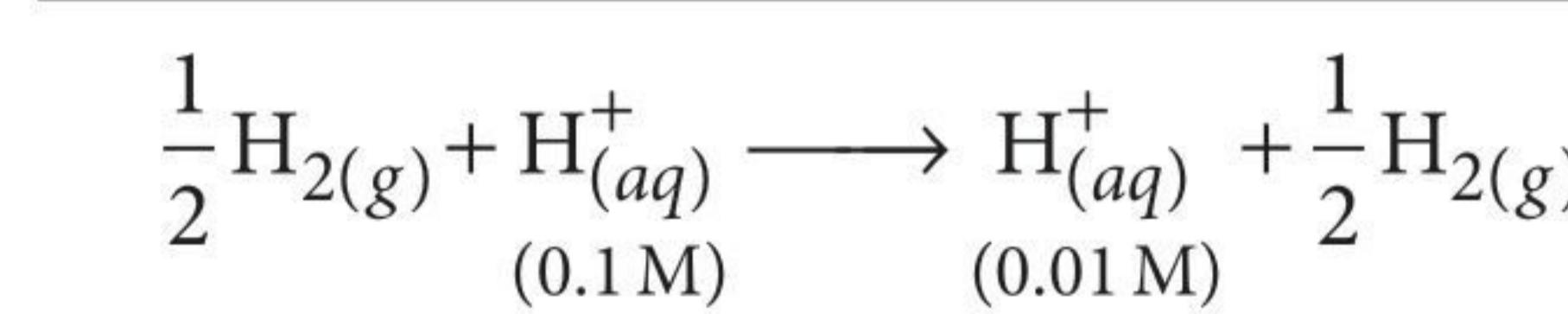
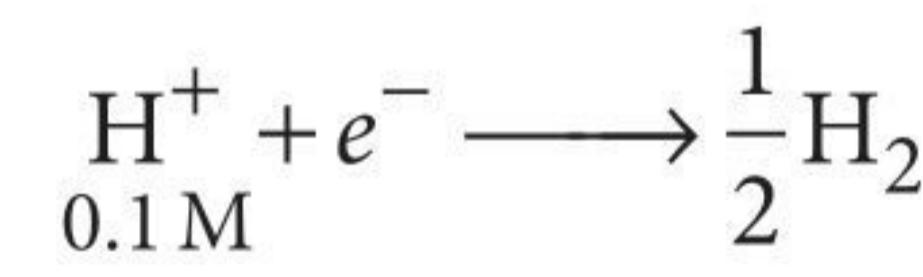
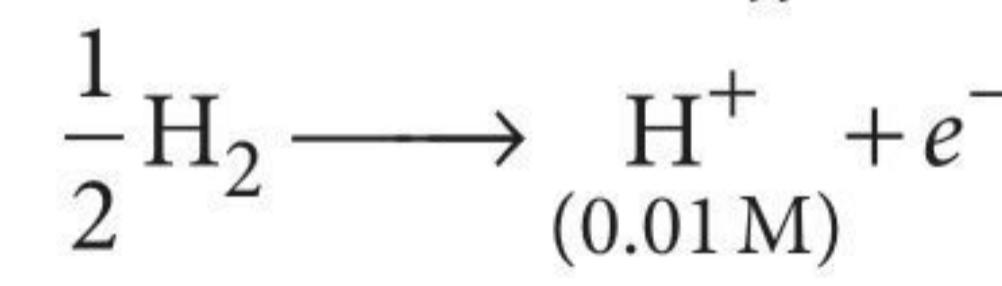
On comparing equation (i) and (ii), we get

$$\frac{\Delta S}{nF} = \frac{R}{F} \Rightarrow \Delta S = nR$$



Option (a) is incorrect.

$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{0.059}{n} \log \frac{[P]}{[R]}$$



Thus,  $E_{\text{cell}}^{\circ}$  for the reaction is zero.

$$E_{\text{cell}} = 0 - \frac{0.059}{1} \log \frac{[\text{H}^+]_2}{[\text{H}^+]_1}$$

$$= -0.059 \log \left( \frac{0.01}{0.1} \right) = -0.059 \log \left( \frac{1}{10} \right)$$

$$= -0.059 \times (-1) = 0.059 \text{ V}$$

So,  $E_{\text{cell}}$  is positive,  $\Delta G$  is negative.

$$\therefore \Delta S = nF \frac{dE}{dt} = +ve$$

∴ Option (b) is correct.

(c) As racemization takes place itself without any external effect. So, it is a spontaneous process.

$$\therefore \Delta H = 0 \quad (\because \text{Same type of bonds break})$$

Hence, if  $\Delta S = +ve$ , only then  $\Delta G$  is negative to make the process spontaneous.

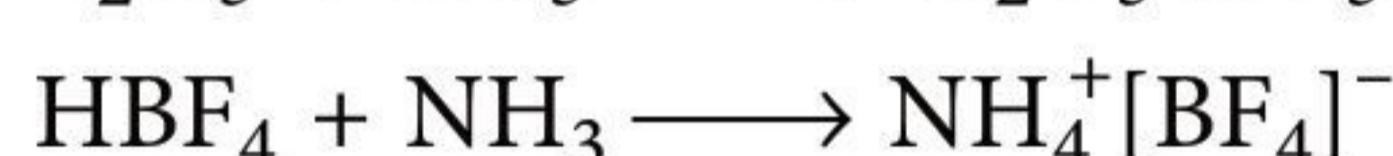
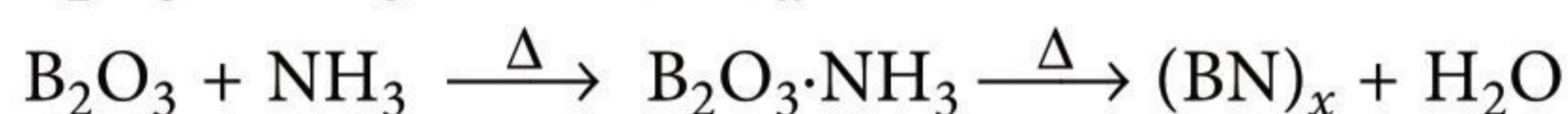
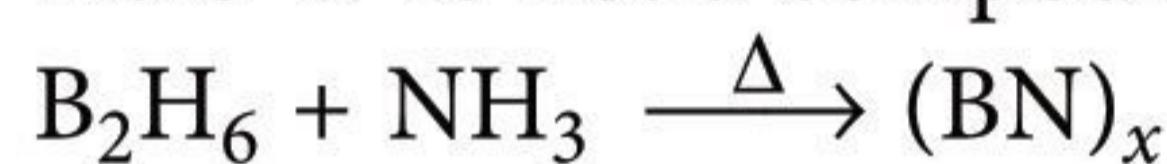
Option (c) is correct.

(d) As the number of particles increases,  $\Delta S > 0$ .

Option (d) is correct.



Here 'B' is not a compound.



**12. (a, b, c) :** Exhaust gases do not contain  $\text{NO}_2$ .

**13. (a, c)**

**14. (b, c) :** Polymerization of neoprene gives natural rubber.

Ethene in presence of peroxide initiator at 350-570 K temperature and 1000-2000 atm pressure, gives low density polythene.

**15. (b) :** X occupies fcc lattice sites and alternate tetrahedral voids.

No. of X atoms per unit cell = 4 + 4 = 8

Volume of unit cell (edge length =  $a$ ) =  $a^3$

$$\text{Volume of each atom} = \frac{4}{3} \pi r^3$$

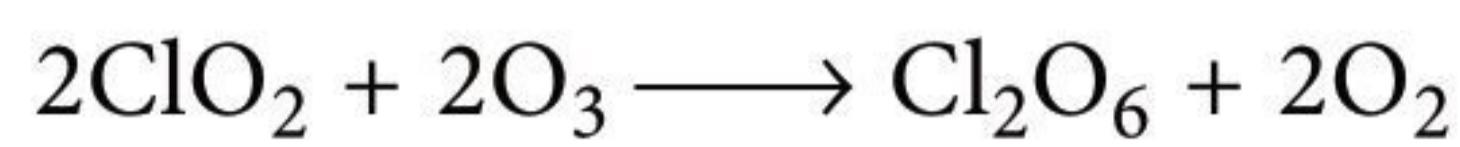
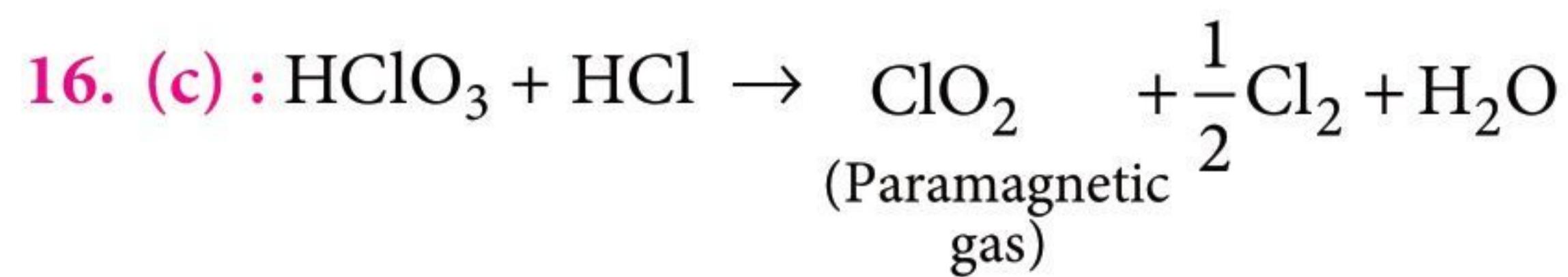
As the atom is present at  $\frac{1}{4}$  distance from corner, so,

$$\frac{\sqrt{3}a}{4} = 2r$$

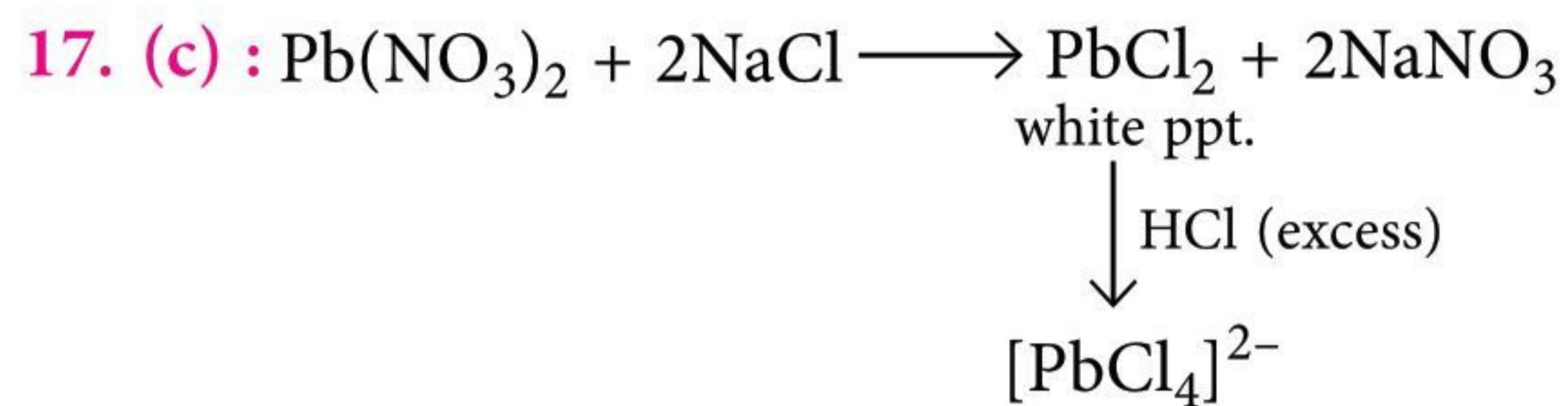
$$\text{Packing efficiency} = n \times \frac{\text{Volume of each atom}}{\text{Volume of unit cell}} \times 100$$

$$= \frac{8 \times \frac{4}{3} \pi r^3}{a^3} \times 100 = \frac{8 \times 4}{3} \pi \frac{r^3}{a^3} \times 100$$

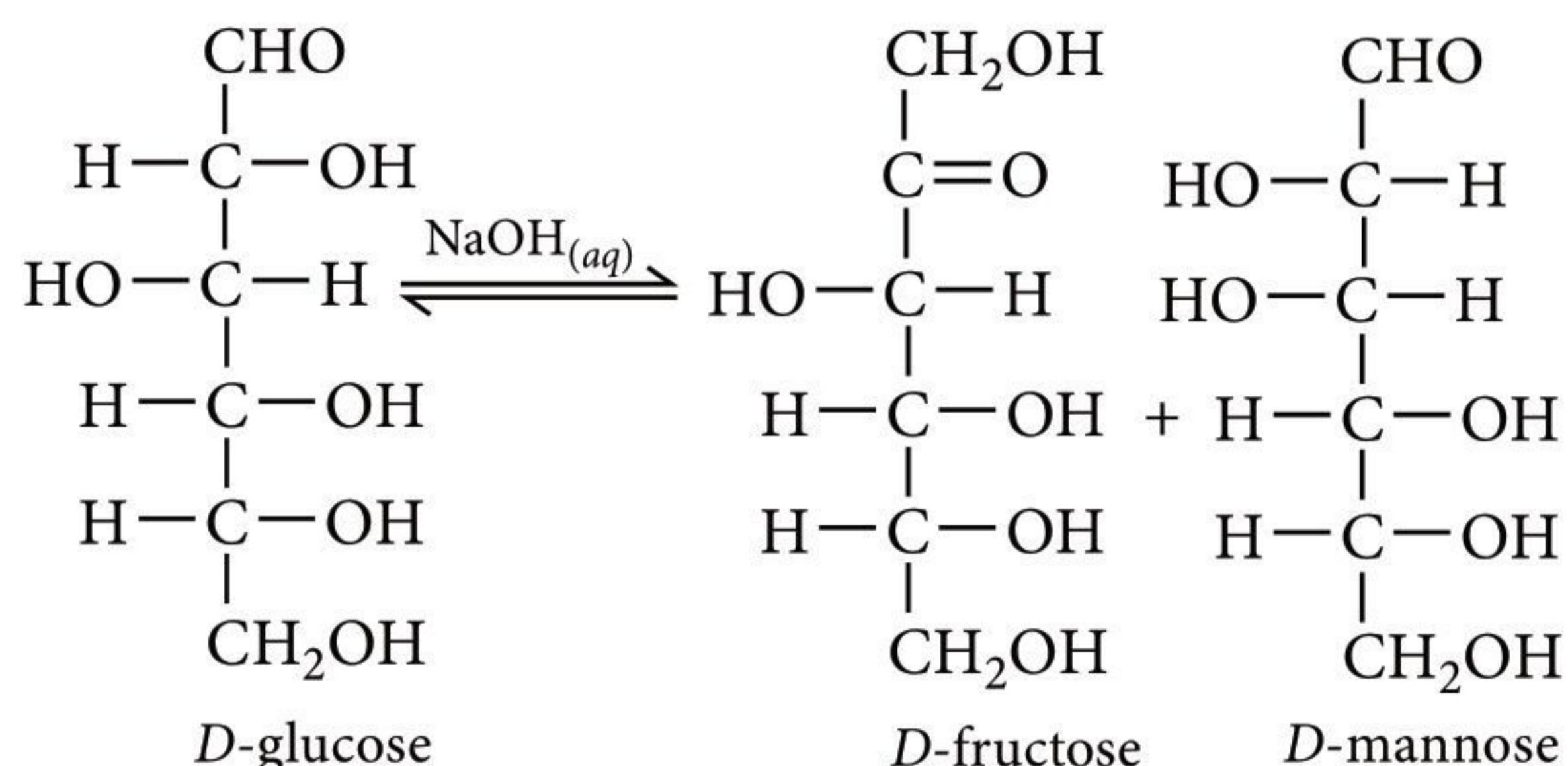
$$= \frac{32\pi}{3} \cdot \frac{3\sqrt{3}a^3}{512} \times 100 = \frac{\sqrt{3}}{16} \pi \times 100 \approx 35\%$$



So,  $\text{Cl}_2\text{O}_6$  is the final product formed by the reaction of  $\text{ClO}_2$  with  $\text{O}_3$ .



**18. (c) :** When D-glucose is treated with aqueous  $\text{NaOH}$ , it results in the formation of D-fructose and D-mannose its is rearrangement reaction.



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# CHAPTERWISE PRACTICE PAPER 2023

# CUET (UG)

## SERIES - II | Electrochemistry | Chemical Kinetics

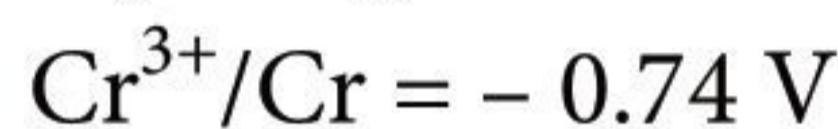
Section II of CUET (UG) is domain specific. In this section of Chemistry 40 questions to be attempted out of 50.

Time Allowed : 45 Minutes

Maximum Marks : 200

### Multiple Choice Questions (MCQs)

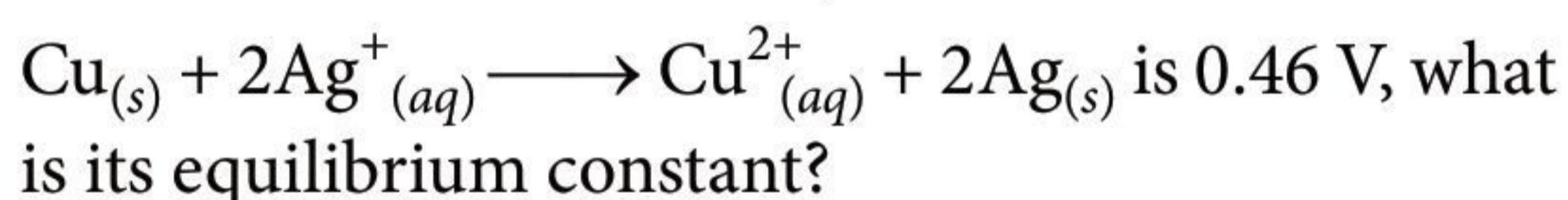
1. Given standard electrode potentials :



Which acts as a better oxidising agent?

(a)  $\text{Mg}^{2+}$  (b)  $\text{Cr}^{3+}$  (c)  $\text{Ag}^+$  (d)  $\text{K}^+$

2. The  $E^\circ$  for the cell reaction,



(a) 15.6 (b)  $4 \times 10^{16}$   
(c)  $4 \times 10^{15}$  (d)  $1.56 \times 10^{15}$

3. The minus sign in rate  $= -\frac{d[A]}{dt}$  indicates the \_\_\_\_\_ in concentration of the \_\_\_\_\_ with time. The rate of a reaction is always \_\_\_\_\_ quantity. The rate of reaction increases with \_\_\_\_\_ in concentration of reactants. The blanks in the question corresponds to

(a) decrease, products, positive, increase  
(b) increase, reactants, negative, decrease  
(c) decrease, reactants, positive, increase  
(d) increase, products, positive, increase

4. For the reaction  $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$ , how are the rate of reaction expressions inter-related

$$\frac{d[\text{H}_2]}{dt} \text{ and } \frac{d[\text{NH}_3]}{dt}?$$

$$(a) -\frac{1}{3} \frac{d[\text{H}_2]}{dt} = +\frac{1}{2} \frac{d[\text{NH}_3]}{dt}$$

$$(b) -\frac{1}{2} \frac{d[\text{H}_2]}{dt} = +\frac{1}{3} \frac{d[\text{NH}_3]}{dt}$$

$$(c) +\frac{1}{2} \frac{d[\text{H}_2]}{dt} = -\frac{1}{3} \frac{d[\text{NH}_3]}{dt}$$

$$(d) +\frac{1}{3} \frac{d[\text{H}_2]}{dt} = -\frac{1}{2} \frac{d[\text{NH}_3]}{dt}$$

5. The rate of disappearance of  $\text{SO}_2$  in the reaction,  $2\text{SO}_2 + \text{O}_2 \rightarrow 2\text{SO}_3$  is  $1.28 \times 10^{-5} \text{ M s}^{-1}$ . The rate of appearance of  $\text{SO}_3$  is

(a)  $0.64 \times 10^{-5} \text{ M s}^{-1}$  (b)  $0.32 \times 10^{-5} \text{ M s}^{-1}$   
(c)  $2.56 \times 10^{-5} \text{ M s}^{-1}$  (d)  $1.28 \times 10^{-5} \text{ M s}^{-1}$

6. For the reaction  $A + B \rightarrow \text{products}$ , what will be the order of reaction with respect to  $A$  and  $B$ ?

Exp.	[A] (mol L <sup>-1</sup> )	[B] (mol L <sup>-1</sup> )	Initial rate (mol L <sup>-1</sup> s <sup>-1</sup> )
1.	$2.5 \times 10^{-4}$	$3 \times 10^{-5}$	$5 \times 10^{-4}$
2.	$5 \times 10^{-4}$	$6 \times 10^{-5}$	$4 \times 10^{-3}$
3.	$1 \times 10^{-3}$	$6 \times 10^{-5}$	$1.6 \times 10^{-2}$

(a) 1 with respect to  $A$  and 2 with respect to  $B$   
(b) 2 with respect to  $A$  and 1 with respect to  $B$   
(c) 1 with respect to  $A$  and 1 with respect to  $B$   
(d) 2 with respect to  $A$  and 2 with respect to  $B$

7. The standard reduction potential values of the three metallic cations  $X$ ,  $Y$  and  $Z$  are 0.52, -3.03, and -1.18 V respectively. The order of reducing power of the corresponding metals is

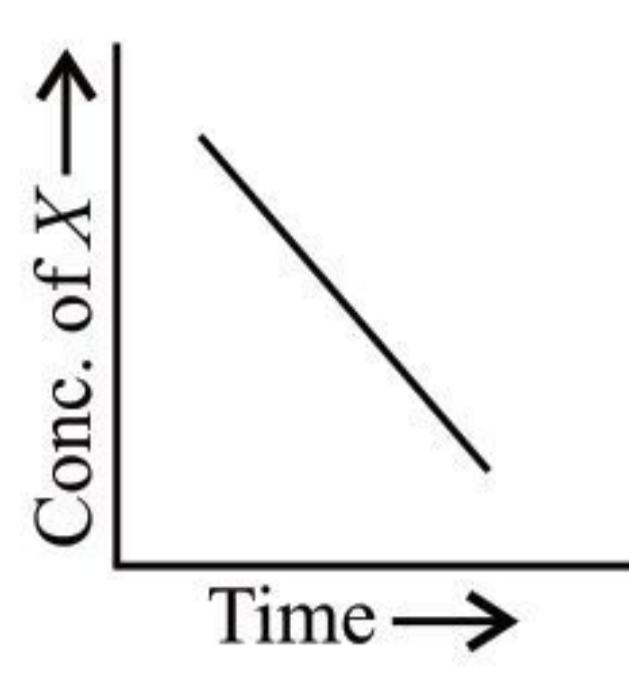
(a)  $Y > Z > X$  (b)  $X > Y > Z$   
(c)  $Z > Y > X$  (d)  $Z > X > Y$

8. The specific conductance of 0.1 M NaCl solution is  $1.06 \times 10^{-2} \text{ ohm}^{-1} \text{ cm}^{-1}$ . Its molar conductance in  $\text{ohm}^{-1} \text{ cm}^2 \text{ mol}^{-1}$  is

(a)  $1.06 \times 10^2$  (b)  $1.06 \times 10^3$

(c)  $1.06 \times 10^4$  (d) 53

9. For a general reaction  $X \rightarrow Y$ , the plot of conc. of  $X$  vs time is given in the figure. What is the order of the reaction and what are the units of rate constant?



(a) Zero,  $\text{mol L}^{-1} \text{s}^{-1}$  (b) First,  $\text{mol L}^{-1} \text{s}^{-1}$   
(c) First,  $\text{s}^{-1}$  (d) Zero,  $\text{L mol}^{-1} \text{s}^{-1}$

10. For a reaction,  $X + Y \rightarrow Z$ , rate  $\propto [X]$ . What are the molecularity and order of reaction?

(a) 2 and 1 (b) 2 and 2 (c) 1 and 1 (d) 1 and 2

11. A first order reaction has a rate constant  $1.15 \times 10^{-3} \text{ s}^{-1}$ . How long will 5 g of this reactant take to reduce to 3 g?

(a) 444 s (b) 400 s (c) 528 s (d) 669 s

12. The atomic weight of Al is 27. When a current of 5 F is passed through a solution of  $\text{Al}^{3+}$  ions, the weight of Al deposited is

(a) 27 g (b) 36 g (c) 45 g (d) 39 g

13. Half-life period of a first order reaction is 10 min. What percentage of the reaction will be completed in 100 min?

(a) 25% (b) 50% (c) 99.9% (d) 75%

14. The rate constant for a first order reaction is  $2 \times 10^{-2} \text{ min}^{-1}$ . The half-life period of reaction is

(a) 69.3 min. (b) 34.65 min.  
(c) 17.37 min. (d) 3.46 min.

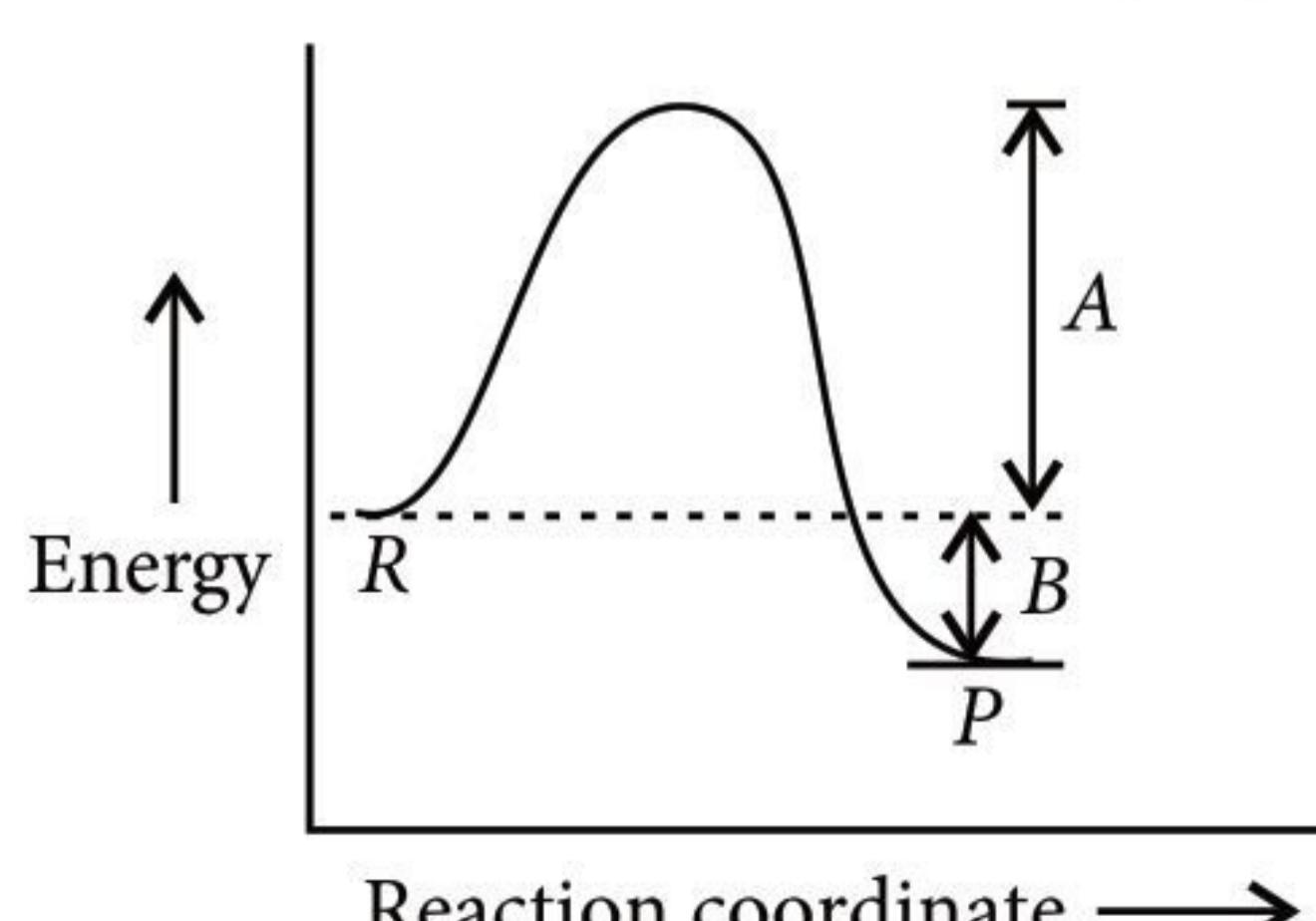
15. In a first order reaction, the concentration of reactant decreases from  $400 \text{ mol L}^{-1}$  to  $25 \text{ mol L}^{-1}$  in 200 seconds. The rate constant for the reaction is

(a)  $1.01386 \text{ s}^{-1}$  (b)  $2 \times 10^{-4} \text{ s}^{-1}$   
(c)  $1.386 \times 10^{-2} \text{ s}^{-1}$  (d)  $3.4 \times 10^{-4} \text{ s}^{-1}$

16. A gas  $z$  is bubbled through a solution containing  $x^-$  and  $y^-$ . If the reduction potential are in the order  $x > y > z$ , then

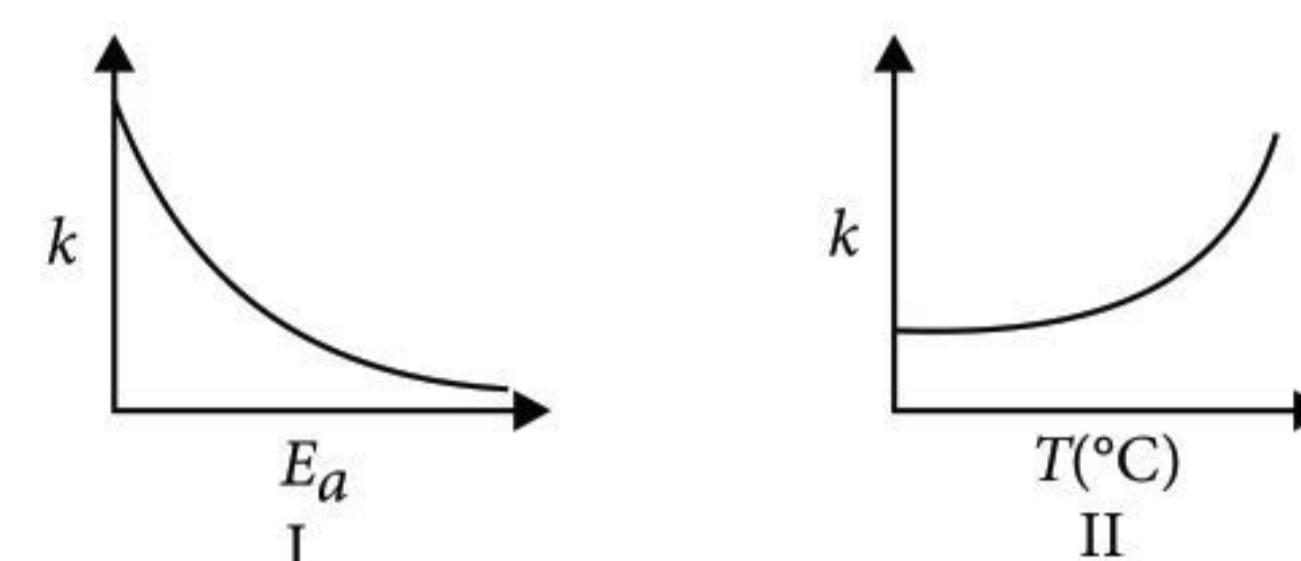
(a)  $y$  will oxidise  $z$  and not  $x$   
(b)  $y$  will oxidise  $x$  and not  $z$   
(c)  $y$  will oxidise both  $x$  and  $z$   
(d)  $y$  will reduce both  $x$  and  $z$ .

17. The energy diagram of a reaction  $P + Q \rightarrow R + S$  is given. What are  $A$  and  $B$  in the graph?



(a)  $A \rightarrow$  activation energy,  $B \rightarrow$  heat of reaction  
(b)  $A \rightarrow$  threshold energy,  $B \rightarrow$  heat of reaction  
(c)  $A \rightarrow$  heat of reaction,  $B \rightarrow$  activation energy  
(d)  $A \rightarrow$  potential energy,  $B \rightarrow$  energy of reaction

18. Which of the following statements is not correct?



(a) For a zero order reaction,  $t_{1/2}$  is proportional to initial concentration.  
(b) The relationship of variation of rate constant with temperature is given by

$$\log \frac{k_2}{k_1} = \frac{E_a}{2.303R} \left[ \frac{T_2 - T_1}{T_1 T_2} \right]$$

(c) The unit of rate constant for a reaction is  $\text{mol}^{1-n} \text{ L}^{n-1} \text{ s}^{-1}$  where  $n$  is order of the reaction.  
(d) The unit of rate of reaction changes with order of reaction.

19. Which of the following statements about the catalyst is true?

(a) A catalyst makes the reaction feasible by making  $\Delta G$  more negative.  
(b) A catalyst makes equilibrium constant more favourable for forward reaction.  
(c) A catalyst accelerates rate of reaction by bringing down the activation energy.  
(d) A catalyst always increases the rate of reaction.

20. Molar conductivity of a solution is

$1.26 \times 10^2 \text{ ohm}^{-1} \text{ cm}^2 \text{ mol}^{-1}$ . Its molarity is 0.01 M.

Its specific conductivity will be

(a)  $1.26 \times 10^{-25} \text{ ohm}^{-1} \text{ cm}^{-1}$   
(b)  $1.26 \times 10^{-3} \text{ ohm}^{-1} \text{ cm}^{-1}$   
(c)  $1.26 \times 10^{-4} \text{ ohm}^{-1} \text{ cm}^{-1}$   
(d)  $0.0063 \text{ ohm}^{-1} \text{ cm}^{-1}$

21. How many Faradays are required to generate one gram atom of magnesium from  $\text{MgCl}_2$ ?

(a) 1 (b) 2 (c) 3 (d) 4

22. In electrolysis of aqueous copper sulphate, the gas at anode and cathode is

(a)  $\text{O}_2$  and  $\text{H}_2$  (b)  $\text{SO}_2$  and  $\text{H}_2$   
(c)  $\text{H}_2$  and  $\text{O}_2$  (d)  $\text{SO}_3$  and  $\text{O}_2$

23. According to Collision theory of reaction rates, increase in the temperature of a reaction will increase the rate of the reaction because of

(a) increase in the velocity of the reacting molecules  
 (b) increase in the number of collisions  
 (c) increase in the number of molecules having the activation energy (threshold energy)  
 (d) none of these.

24. For a chemical reaction at 27°C, the activation energy is 600 R. The ratio of the rate constants at 327°C to that of at 27°C will be  
 (a) 2 (b) 40 (c)  $e$  (d)  $e^2$

25. How many Faradays are required to reduce 1 mol of  $\text{Cr}_2\text{O}_7^{2-}$  to  $\text{Cr}^{3+}$  in acidic medium?  
 (a) 2 (b) 3 (c) 5 (d) 6

26. Zinc is used to protect iron from rusting because  
 (a)  $E^\circ_{\text{red}}$  of Zn >  $E^\circ_{\text{red}}$  of Fe  
 (b)  $E^\circ_{\text{ox}}$  of Zn >  $E^\circ_{\text{ox}}$  of Fe  
 (c) zinc does not melt easily  
 (d) zinc is cheap.

27. A secondary cell is one which  
 (a) contains 30% solution of hydroboric acid  
 (b) can be recharged by passing current through it in the same direction  
 (c) can be recharged by passing current through it in the opposite direction  
 (d) cannot be recharged.

28. The rate of a reaction quadruples when the temperature changes from 300 K to 310 K. The activation energy of this reaction is  
 (Assume activation energy and pre-exponential factor are independent of temperature;  $\ln 2 = 0.693$ ;  $R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$ )  
 (a) 53.6  $\text{kJ mol}^{-1}$  (b) 26.8  $\text{kJ mol}^{-1}$   
 (c) 107.2  $\text{kJ mol}^{-1}$  (d) 214.4  $\text{kJ mol}^{-1}$

29. For a first order reaction,  $(A) \rightarrow$  products, the concentration of A changes from 0.1 M to 0.025 M in 40 minutes. The rate of reaction when the concentration of A is 0.01 M is  
 (a)  $3.47 \times 10^{-4} \text{ M/min}$  (b)  $3.47 \times 10^{-5} \text{ M/min}$   
 (c)  $1.73 \times 10^{-4} \text{ M/min}$  (d)  $1.73 \times 10^{-5} \text{ M/min}$

30. From the following data at 25°C,  
 $\text{Cr}_{(aq)}^{3+} + e^- \rightarrow \text{Cr}_{(aq)}^{2+}, E^\circ = -0.424 \text{ V}$   
 $\text{Cr}_{(aq)}^{2+} + 2e^- \rightarrow \text{Cr}_{(s)}, E^\circ = -0.900 \text{ V}$   
 Find  $E^\circ$  at 25°C for the reaction,  
 $\text{Cr}^{3+} + 3e^- \rightarrow \text{Cr}_{(s)}$   
 (a) -0.741 V (b) -1.324 V  
 (c) -0.476 V (d) +0.741 V

31. In an electrochemical cell, the reaction will be feasible when  
 (a)  $\Delta G = -\text{ve}, E = +\text{ve}$  (b)  $\Delta G = +\text{ve}, E = -\text{ve}$   
 (c)  $\Delta G = 0, E = -\text{ve}$  (d)  $\Delta G = 0, E = 0$

32. For the non-stoichiometric reaction:  
 $2A + B \rightarrow C + D$ , the following kinetic data were obtained in three separate experiments, all at 298 K.

Initial concentration [A]	Initial concentration [B]	Initial rate of formation of C ( $\text{mol L}^{-1} \text{s}^{-1}$ )
0.1 M	0.1 M	$1.2 \times 10^{-3}$
0.1 M	0.2 M	$1.2 \times 10^{-3}$
0.2 M	0.1 M	$2.4 \times 10^{-3}$

The rate law for the formation of C is  
 (a)  $\frac{dC}{dt} = k[A]$  (b)  $\frac{dC}{dt} = k[A][B]$   
 (c)  $\frac{dC}{dt} = k[A]^2[B]$  (d)  $\frac{dC}{dt} = k[A][B]^2$

33. For a chemical reaction, rate law is, rate =  $k[A]^2[B]$ . If [A] is doubled at constant [B], the rate of reaction  
 (a) increases by a factor of 8  
 (b) increases by a factor of 4  
 (c) increases by a factor of 3  
 (d) increases by a factor of 2.

34. For a reaction of order  $n$ , the unit of the rate constant is  
 (a)  $\text{mol}^{1-n} \text{ L}^{n-1} \text{ s}^{-1}$  (b)  $\text{mol}^{1-n} \text{ L}^{1-n} \text{ s}^{-1}$   
 (c)  $\text{mol}^{1-n} \text{ L}^{1-n} \text{ s}$  (d)  $\text{mol}^{1-n} \text{ L}^{2n} \text{ s}^{-1}$

### Assertion & Reason Based MCQs

For question numbers 35-38, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) If both assertion and reason are correct and reason is the correct explanation of assertion.  
 (b) If both assertion and reason are correct but reason is not the correct explanation of assertion.  
 (c) If assertion is correct but reason is wrong.  
 (d) If assertion is wrong but reason is correct.

35. **Assertion :** The electrical resistance of any object decreases with increase in its length.

**Reason :** The electrical resistance of any object decreases with increase in its area of cross-section.

36. **Assertion :** If  $\lambda_{\text{Na}^+}^\circ$  and  $\lambda_{\text{Cl}^-}^\circ$  are molar limiting conductivities of the sodium and chloride ions

respectively, then the limiting molar conductivity for sodium chloride is given by the equation,

$$\Lambda_{\text{NaCl}}^{\circ} = \Lambda_{\text{Na}^+}^{\circ} + \Lambda_{\text{Cl}^-}^{\circ}$$

**Reason :** This is according to Kohlrausch law of independent migration of ions.

37. **Assertion :** Formation of HI is a bimolecular reaction.

**Reason :** Two molecules of reactants are involved in this reaction.

38. **Assertion :** Half-life period of a reaction of first order is independent of initial concentration.

**Reason :** Half-life period for a first order reaction,

$$t_{1/2} = \frac{2.303}{k} \log 2.$$

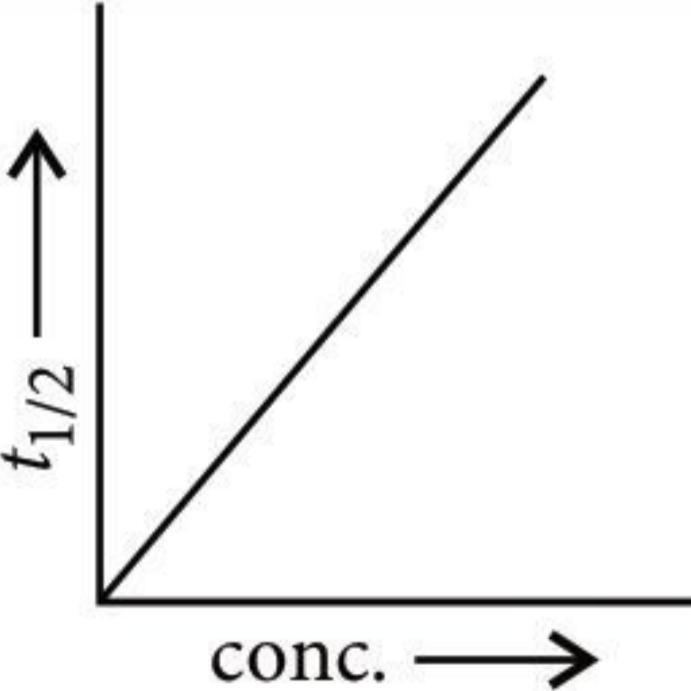
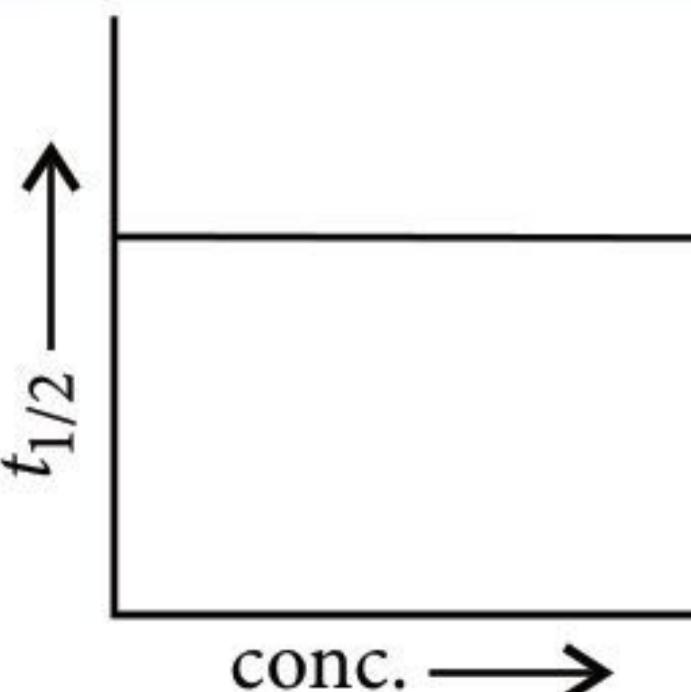
### Match the Columns

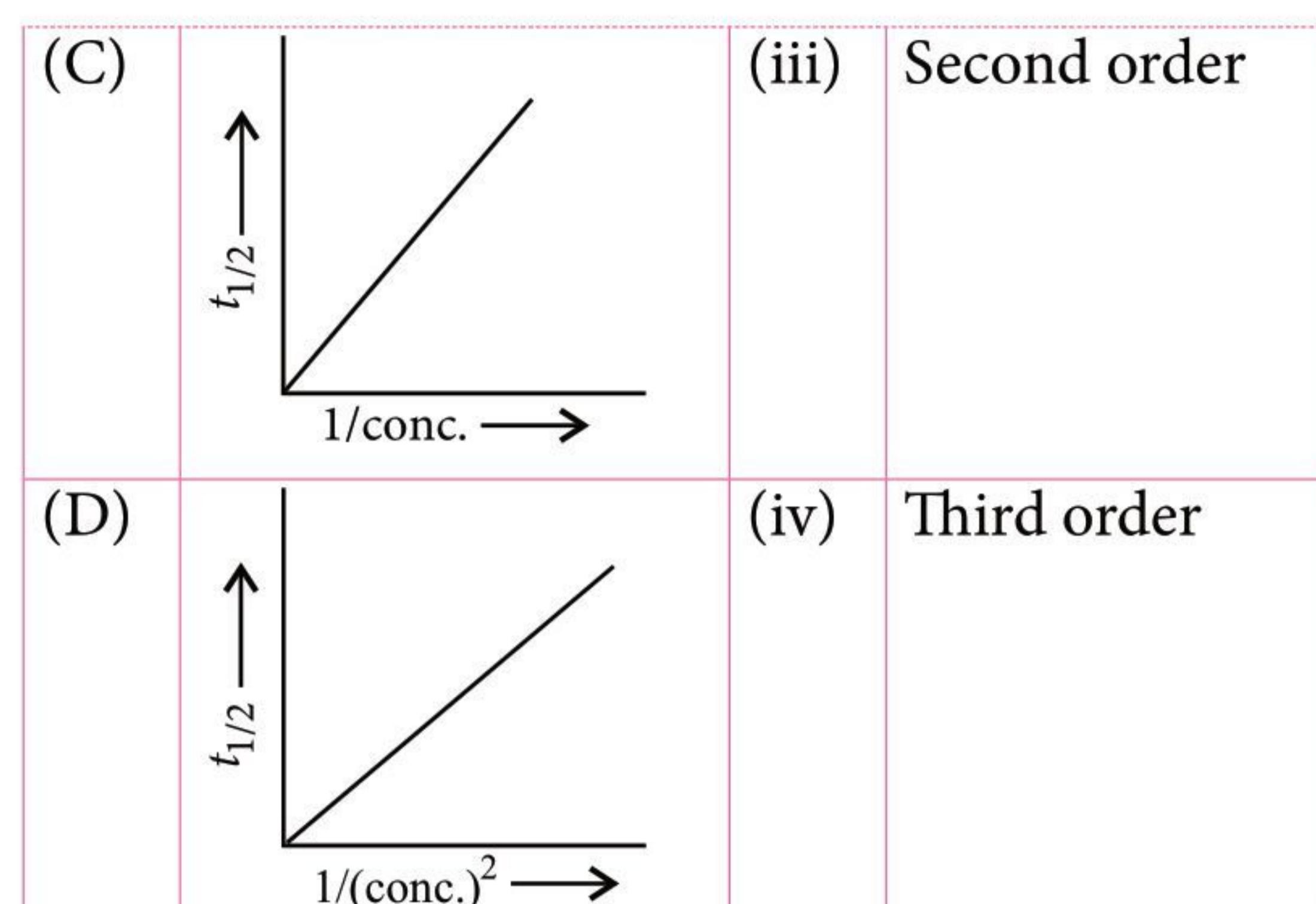
39. Match the column I with column II and mark the appropriate choice.

Column I		Column II	
(A)	Kohlrausch's law	(i)	$\Lambda_{eq}^{\circ} = \Lambda_c^{\circ} + \Lambda_a^{\circ}$
(B)	Molar conductivity	(ii)	$\Lambda_m = \frac{\kappa}{C}$
(C)	Degree of dissociation	(iii)	$\alpha = \frac{\Lambda_m}{\Lambda_m^{\circ}}$
(D)	Dissociation constant	(iv)	$K_a = \frac{C\alpha^2}{1-\alpha}$

(a) (A)  $\rightarrow$  (iii), (B)  $\rightarrow$  (ii), (C)  $\rightarrow$  (i), (D)  $\rightarrow$  (iv)  
 (b) (A)  $\rightarrow$  (i), (B)  $\rightarrow$  (ii), (C)  $\rightarrow$  (iii), (D)  $\rightarrow$  (iv)  
 (c) (A)  $\rightarrow$  (iv), (B)  $\rightarrow$  (iii), (C)  $\rightarrow$  (ii), (D)  $\rightarrow$  (i)  
 (d) (A)  $\rightarrow$  (ii), (B)  $\rightarrow$  (i), (C)  $\rightarrow$  (iii), (D)  $\rightarrow$  (iv)

40. Match the plots in column I with their orders in column II and mark the appropriate choice.

Column I		Column II	
(A)		(i)	Zero order
(B)		(ii)	First order



(a) (A)  $\rightarrow$  (iii), (B)  $\rightarrow$  (ii), (C)  $\rightarrow$  (i), (D)  $\rightarrow$  (iv)  
 (b) (A)  $\rightarrow$  (i), (B)  $\rightarrow$  (ii), (C)  $\rightarrow$  (iii), (D)  $\rightarrow$  (iv)  
 (c) (A)  $\rightarrow$  (iv), (B)  $\rightarrow$  (iii), (C)  $\rightarrow$  (ii), (D)  $\rightarrow$  (i)  
 (d) (A)  $\rightarrow$  (ii), (B)  $\rightarrow$  (i), (C)  $\rightarrow$  (iii), (D)  $\rightarrow$  (iv)

### Case Based MCQs

**Case I : Read the passage given below and answer the following questions from 41 to 45.**

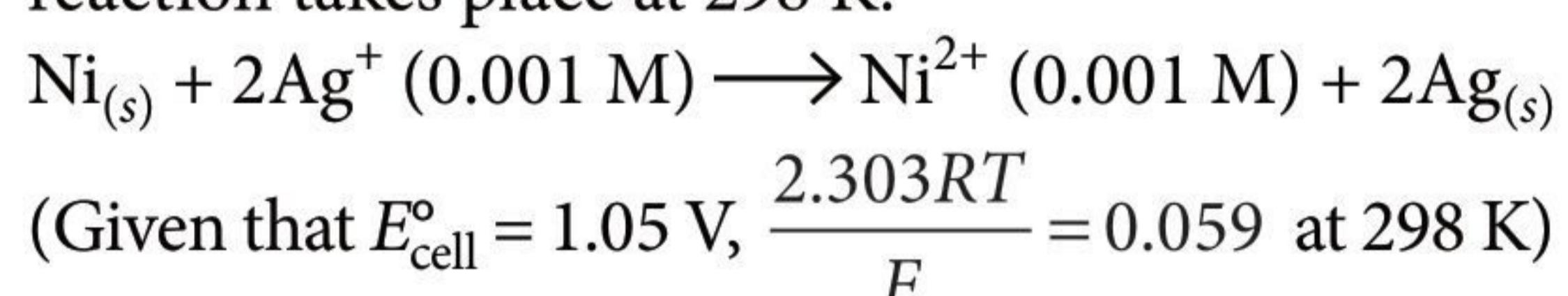
Nernst equation relates the reduction potential of an electrochemical reaction to the standard potential and activities of the chemical species undergoing oxidation and reduction.

Let us consider the reaction,  $M^{n+}_{(aq)} + ne^- \rightarrow M_{(s)}$   
 For this reaction, the electrode potential measured with respect to standard hydrogen electrode can be given as

$$E_{(M^{n+}/M)} = E_{(M^{n+}/M)}^{\circ} - \frac{RT}{nF} \ln \frac{[M]}{[M^{n+}]}$$

The following questions are multiple choice questions. Choose the most appropriate answer :

41. Calculate the emf of the cell in which following reaction takes place at 298 K.



(a) 1.0385 V (b) 1.385 V  
 (c) 0.9615 V (d) 1.05 V

42. For a cell involving one electron,  $E_{\text{cell}}^{\circ} = 0.59 \text{ V}$  at 298 K, the equilibrium constant for the cell reaction is [Given that  $\frac{2.303RT}{F} = 0.059 \text{ V}$  at  $T = 298 \text{ K}$ ]

(a)  $1.0 \times 10^{30}$  (b)  $1.0 \times 10^2$   
 (c)  $1.0 \times 10^5$  (d)  $1.0 \times 10^{10}$

43. Cell equation :  $A + 2B^+ \rightarrow A^{2+} + 2B$   
 $A^{2+} + 2e^- \rightarrow A$ ;  $E^{\circ} = + 0.34 \text{ V}$

and  $\log_{10} K_c = 15.6$  at 300 K for cell reactions.

Find  $E^\circ$  for  $B^+ + e^- \rightarrow B$ .

$$\left[ \text{Given: } \frac{2.303 RT}{nF} = 0.059 \text{ at } 300\text{ K} \right]$$

(a) 0.80 V (b) 1.26 V  
(c) -0.54 V (d) +0.94 V

44. What will be the emf of the following cell at 25°C?



(a) 0.828 V (b) 0.0413 V  
(c) -0.0413 V (d) -0.828 V

45. The reduction potential of a half cell consisting of a Pt electrode dipped in 2.0 M  $\text{Fe}^{2+}$  and 0.02 M  $\text{Fe}^{3+}$  solution is, if  $E^\circ_{\text{Fe}^{3+}/\text{Fe}^{2+}} = +0.771 \text{ V}$

(a) -0.046 V (b) 0.563 V  
(c) +0.046 V (d) 0.653 V

**Case II : Read the passage given below and answer the following questions from 46 to 50.**

In a reaction, the rates of disappearance of different reactants or rates of formation of different products may not be equal but rate of reaction at any instant of time has the same value expressed in terms of any reactant or product. Further, the rate of reaction may not depend upon the stoichiometric coefficients of the balanced chemical equation. The exact powers of molar concentrations of reactants on which rate depends are found experimentally and expressed in terms of 'order of reaction.' Each reaction has a characteristic rate constant depends upon temperature. The units of the rate constant depend upon the order of reaction.

**The following questions are multiple choice questions. Choose the most appropriate answer :**

46. The rate constant of a reaction is found to be  $3 \times 10^{-3} \text{ mol}^{-2} \text{ L}^2 \text{ sec}^{-1}$ . The order of the reaction is  
(a) 0.5 (b) 2 (c) 3 (d) 1

47. In the reaction,  $A + 3B \rightarrow 2C$ , the rate of formation of C is

(a) the same as rate of consumption of A  
(b) the same as the rate of consumption of B  
(c) twice the rate of consumption of A  
(d) 3/2 times the rate of consumption of B.

48. Rate of a reaction can be expressed by following rate expression, Rate =  $k[A]^2 [B]$ , if concentration of A is increased by 3 times and concentration of B is increased by 2 times, how many times rate of reaction increases?

(a) 9 times (b) 27 times  
(c) 18 times (d) 8 times

49. The rate of a certain reaction is given by, rate =  $k[\text{H}^+]^n$ .

The rate increases 100 times when the pH changes from 3 to 1. The order (n) of the reaction is

(a) 2 (b) 0 (c) 1 (d) 1.5

50. In a chemical reaction  $A + 2B \rightarrow \text{products}$ , when concentration of A is doubled, rate of the reaction increases 4 times and when concentration of B alone is doubled rate continues to be the same. The order of the reaction is

(a) 1 (b) 2 (c) 3 (d) 4

### SOLUTIONS

1. (c) : Higher the value of reduction potential, better will be the oxidising agent.

2. (c) :  $E_{\text{cell}}^\circ = \frac{0.059}{2} \log K_c$  or  $\log K_c = \frac{0.46 \times 2}{0.059} = 15.6$   
 $\therefore K_c = 4 \times 10^{15}$

3. (c)

4. (a) :  $\text{H}_2$  decreases three times as fast as that of  $\text{N}_2$  while  $\text{NH}_3$  increases twice as fast as that of  $\text{N}_2$  decreases.

Hence, Rate =  $-\frac{1}{3} \frac{d[\text{H}_2]}{dt} = +\frac{1}{2} \frac{d[\text{NH}_3]}{dt}$

5. (d) : The rate of disappearance of  $\text{SO}_2$  and the rate of formation of  $\text{SO}_3$  are same.

6. (b)

7. (a) : Smaller the value of reduction potential stronger is the reducing agent.

8. (a) : Applying,  $\Lambda_m = \kappa \times \frac{1000}{\text{Molarity}}$   
 $= 1.06 \times 10^{-2} \times \frac{1000}{0.1} = 1.06 \times 10^2 \text{ ohm}^{-1} \text{ cm}^2 \text{ mol}^{-1}$

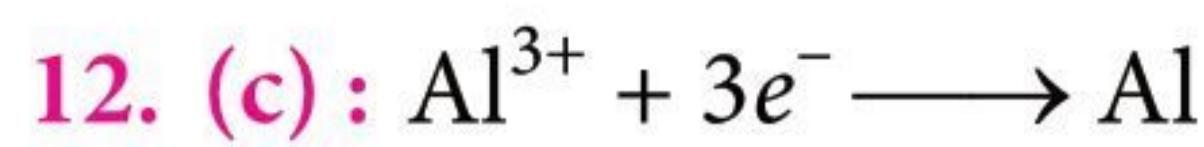
9. (a) : For a zero order reaction, rate =  $k = \frac{dx}{dt}$   
Units of  $k = \text{mol L}^{-1} \text{ s}^{-1}$

10. (a)

11. (a) :  $t = \frac{2.303}{k} \log \frac{[R_0]}{[R]} = \frac{2.303}{1.15 \times 10^{-3}} \log \frac{5}{3}$   
 $= 2.00 \times 10^3 \log 1.667 = 2 \times 10^3 \times 0.2219 = 444 \text{ s}$

### MONTHLY TEST DRIVE CLASS XII ANSWER KEY

1. (c)	2. (d)	3. (b)	4. (a)	5. (a)
6. (b)	7. (b)	8. (c)	9. (d)	10. (a)
11. (c)	12. (c)	13. (b)	14. (a)	15. (c)
16. (a)	17. (c)	18. (c)	19. (b)	20. (a,b,c)
21. (b)	22. (b,c)	23. (b)	24. (9)	25. (6)
26. (3)	27. (b)	28. (b)	29. (b)	30. (b)



$$E_{\text{Al}} = \frac{27}{3} = 9$$

$$w_{\text{Al}} = E_{\text{Al}} \times \text{No. of Faradays} = 9 \times 5 = 45 \text{ g}$$

13. (c) :  $\frac{0.693}{t_{1/2}} = \frac{2.303}{t} \log \frac{a}{a-x}$

$$\frac{0.693}{10} = \frac{2.303}{100} \log \frac{100}{100-x} \Rightarrow x = 99.9\%$$

14. (b) :  $t_{1/2} = \frac{0.693}{k} = \frac{0.693}{2 \times 10^{-2}} = 34.65 \text{ min.}$

15. (c) : For first order reaction,

$$k = \frac{2.303}{t} \log \frac{a}{(a-x)} = \frac{2.303}{200} \log \frac{400}{25} \\ = \frac{2.303}{200} \times 1.204 = 0.01386 \text{ s}^{-1} = 1.386 \times 10^{-2} \text{ s}^{-1}$$

16. (a) : More is the value of reduction potential, more is the tendency to get reduced. So as  $z$  gas has lowest reduction potential, therefore,  $z$  will be oxidised easily.

17. (a)

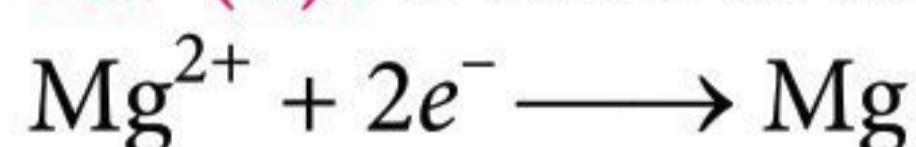
18. (d) : The unit of rate of reaction is  $\text{mol L}^{-1} \text{ s}^{-1}$ . It does not change with order.

19. (c)

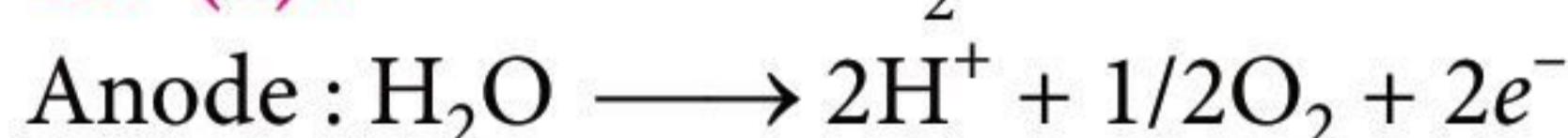
20. (b) : Applying,  $\Lambda_m = \frac{\kappa \times 1000}{\text{Molarity}}$

$$\kappa = \frac{1.26 \times 10^2 \times 0.01}{1000} = 1.26 \times 10^{-3} \text{ ohm}^{-1} \text{ cm}^{-1}$$

21. (b) : 1 mole of electrons = 1 F



2 moles of electrons = 2 F



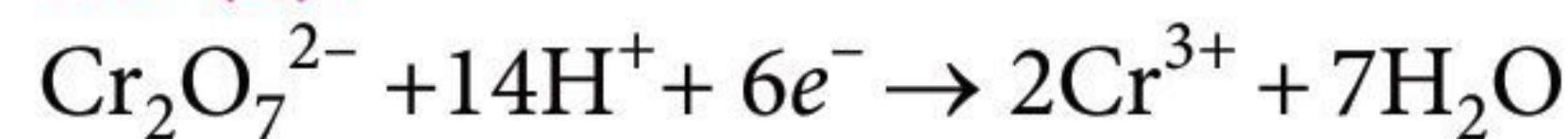
23. (c) : When temperature is increased, the number of active molecules (i.e. the molecules with activation energy) increases, therefore, the number of effective collisions will increase and the rate of reaction will also increase.

24. (c) :  $\ln \frac{k_2}{k_1} = \frac{E_a}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$

$$\text{or, } \ln \frac{k_2}{k_1} = \frac{600R}{R} \left( \frac{1}{300} - \frac{1}{600} \right) = \frac{600R}{300R} \left( \frac{2-1}{2} \right)$$

$$\text{or, } \ln \frac{k_2}{k_1} = 2 \left( \frac{1}{2} \right) = 1 \text{ or } \ln \frac{k_2}{k_1} = \ln e \Rightarrow \frac{k_2}{k_1} = e$$

25. (d) : In acidic medium,



Thus,  $n = 6$

Hence, 6 F charge is required to reduce 1 mol of  $\text{Cr}_2\text{O}_7^{2-}$  to  $\text{Cr}^{3+}$  in acidic medium.

26. (b)

27. (c)

28. (c) :  $\ln \frac{k_2}{k_1} = \frac{E_a}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$

$$\ln 4 = \frac{E_a}{R} \left( \frac{1}{300} - \frac{1}{310} \right) \Rightarrow \ln 4 = \frac{E_a}{R} \left( \frac{10}{300 \times 310} \right)$$

$$E_a = \frac{1.386 \times 8.314 \times 300 \times 310}{10}$$

$$= 107207.87 \text{ J mol}^{-1} = 107.207 \text{ kJ mol}^{-1}$$

29. (a) : For the first order reaction,  $k = \frac{2.303}{t} \log \frac{a}{a-x}$

$a = 0.1 \text{ M}, a-x = 0.025 \text{ M}, t = 40 \text{ min}$

$$k = \frac{2.303}{40} \log \frac{0.1}{0.025} = \frac{2.303}{40} \log 4 = 0.0347 \text{ min}^{-1}$$

$[A] \rightarrow \text{product}$

Thus, rate =  $k[A]$

$$\text{rate} = 0.0347 \times 0.01 \text{ M min}^{-1} = 3.47 \times 10^{-4} \text{ M min}^{-1}$$

30. (a) :  $\text{Cr}_{(aq)}^{3+} + e^- \rightarrow \text{Cr}_{(aq)}^{2+}; -1 \times F \times (-0.424) = 0.424 \text{ F}$  ... (i)

$$\text{Cr}_{(aq)}^{2+} + 2e^- \rightarrow \text{Cr}_{(s)}; -2 \times F \times (-0.900) = 1.8 \text{ F} \quad \dots \text{(ii)}$$

Adding eq (i) and (ii)

$$\text{Cr}^{3+} + 3e^- \rightarrow \text{Cr}_{(s)}; E^\circ = - \left( \frac{0.424 \text{ F} + 1.8 \text{ F}}{3 \text{ F}} \right) = -0.741 \text{ V}$$

31. (a) : For a spontaneous reaction,  $\Delta G$  should be -ve which is possible only when  $E$  is +ve as  $\Delta G = -nFE$ .

32. (a) : For the reaction,  $2A + B \rightarrow C + D$

Rate of reaction

$$= -\frac{1}{2} \frac{d[A]}{dt} = -\frac{d[B]}{dt} = \frac{d[C]}{dt} = \frac{d[D]}{dt}$$

Now, rate of reaction,  $\frac{d[C]}{dt} = k[A]^x [B]^y$

From table,

$$1.2 \times 10^{-3} = k(0.1)^x (0.1)^y \quad \dots \text{(i)}$$

$$1.2 \times 10^{-3} = k(0.1)^x (0.2)^y \quad \dots \text{(ii)}$$

$$2.4 \times 10^{-3} = k(0.2)^x (0.1)^y \quad \dots \text{(iii)}$$

On dividing equation (i) by (ii), we get

$$\frac{1.2 \times 10^{-3}}{1.2 \times 10^{-3}} = \frac{k(0.1)^x (0.1)^y}{k(0.1)^x (0.2)^y}; 1 = \left( \frac{1}{2} \right)^y \Rightarrow y = 0$$

On dividing equation (i) by (iii), we get

$$\frac{1.2 \times 10^{-3}}{2.4 \times 10^{-3}} = \frac{k(0.1)^x (0.1)^y}{k(0.2)^x (0.1)^y} ; \left(\frac{1}{2}\right)^1 = \left(\frac{1}{2}\right)^x \Rightarrow x = 1$$

$$\text{Hence, } \frac{d[C]}{dt} = k[A]^1[B]^0 = k[A]$$

33. (b): Rate =  $k[A]^2[B]$

If  $[A]$  is doubled at constant  $[B]$ ,

$$\text{rate} = k[2A]^2[B] = 4k[A]^2[B]$$

The rate of reaction is increased by a factor of 4.

34. (a): For  $n^{\text{th}}$  order reaction, Rate =  $k[a]^n$

$$k = \frac{\text{Rate}}{[a]^n} = \frac{\text{mol L}^{-1}\text{s}^{-1}}{(\text{mol L}^{-1})^n} = \frac{\text{mol L}^{-1}\text{s}^{-1}}{\text{mol}^n\text{L}^{-n}} = \text{mol}^{1-n}\text{L}^{n-1}\text{s}^{-1}$$

35. (d): The electrical resistance of any object is directly proportional to its length,  $l$ , and inversely proportional to its area of cross-section,  $A$ . So, it increases with increase in length of object and decreases with increase in area of cross-section of object.

36. (a): According to Kohlrausch law, "limiting molar conductivity of an electrolyte can be represented as the sum of the individual contributions of the anion and cation of the electrolyte."

37. (a): A bimolecular reaction may involve combination of two molecules or exchange of atoms or groups of atoms between the two reactant molecules.

38. (a): For first order reaction,

$$t_{1/2} = \frac{2.303}{k} \log 2 = \frac{0.693}{k}$$

39. (b)

40. (b)

41. (c): According to Nernst equation,

$$E = E_{\text{cell}}^{\circ} - \frac{0.059}{n} \log \frac{[\text{Ni}^{2+}]}{[\text{Ag}^{+}]^2} \Rightarrow E_{\text{cell}}^{\circ} = 1.05 \text{ (Given)}$$

$$E = 1.05 - \frac{0.059}{2} \log \frac{(0.001)}{(0.001)^2} = 1.05 - \frac{0.059}{2} \log 10^3 \\ = 1.05 - \frac{0.059 \times 3}{2} = 1.05 - 0.0885 = 0.9615 \text{ V}$$

42. (d): According to Nernst equation,

$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{0.059}{n} \log Q_c$$

At equilibrium  $E_{\text{cell}} = 0$ ,  $\therefore Q_c = K_c$

$$E_{\text{cell}}^{\circ} = \frac{0.059}{n} \log K_c \Rightarrow 0.59 = \frac{0.059}{1} \log K_c$$

$$K_c = \text{antilog } 10 \Rightarrow K_c = 1 \times 10^{10}$$

43. (a):  $E_{\text{cell}}^{\circ} = \frac{0.059}{2} \log K_c$

$$E_{B^+/B}^{\circ} - E_{A^{2+}/A}^{\circ} = \frac{0.059}{2} \log K_c$$

$$E_{B^+/B}^{\circ} - 0.34 \text{ V} = \frac{0.059}{2} \times 15.6$$

$$E_{B^+/B}^{\circ} = 0.46 + 0.34 = 0.80 \text{ V}$$

44. (b):  $E = E^{\circ} - \frac{0.0591}{n} \log Q$

$E^{\circ} = 0$  (as both the electrode are made up of Ag)

$$= 0 - \frac{0.0591}{1} \log \left( \frac{0.01}{0.05} \right) = 0.0413 \text{ V}$$

45. (d): Reduction half cell :

$$\text{Fe}^{3+} + e^- \rightarrow \text{Fe}^{2+}; E_{\text{Fe}^{3+}/\text{Fe}^{2+}}^{\circ} = 0.771 \text{ V}$$

According of Nernst equation;

$$E_{\text{Fe}^{3+}/\text{Fe}^{2+}} = E_{\text{Fe}^{3+}/\text{Fe}^{2+}}^{\circ} - \frac{0.059}{1} \log \frac{[\text{Fe}^{2+}]}{[\text{Fe}^{3+}]} \\ = 0.771 - 0.059 \log \frac{(2)}{(0.02)} = 0.771 - 0.059 \log \frac{200}{2} \\ = 0.771 - 0.059 \log 10^2 = 0.771 - 0.059 \times 2 = 0.653 \text{ V}$$

46. (c): Unit of  $k$  for  $n^{\text{th}}$  order =  $(\text{mol L}^{-1})^{1-n} \text{ sec}^{-1}$  ... (i)

Here,  $k = 3 \times 10^{-3} \text{ mol}^{-2} \text{ L}^2 \text{ sec}^{-1}$

Unit of  $k = \text{mol}^{-2} \text{ L}^2 \text{ sec}^{-1} \Rightarrow (\text{mol L}^{-1})^{-2} \text{ sec}^{-1}$  ... (ii)

Comparing (i) and (ii) we get,  $1 - n = -2 \Rightarrow n = 3$

47. (c): Rate =  $-\frac{d[A]}{dt} = -\frac{1}{3} \frac{d[B]}{dt} = \frac{1}{2} \frac{d[C]}{dt}$

$$\frac{d[C]}{dt} = 2 \times \left[ -\frac{d[A]}{dt} \right]$$

48. (c): Given,  $R_1 = k[A]^2 [B]$

According to question,  $R_2 = k[3A]^2 [2B]$

$$= k \times 9 [A]^2 \times 2 [B] = 18 \times k [A]^2 [B] = 18 R_1$$

49. (c): Rate ( $r$ ) =  $k[\text{H}^+]^n$

When pH = 3;  $[\text{H}^+] = 10^{-3}$

and when pH = 1;  $[\text{H}^+] = 10^{-1}$

$$\therefore \frac{r_1}{r_2} = \frac{k(10^{-3})^n}{k(10^{-1})^n} \Rightarrow \frac{1}{100} = \left( \frac{10^{-3}}{10^{-1}} \right)^n \quad (\because r_2 = 100 r_1)$$

$$\Rightarrow (10^{-2})^1 = (10^{-2})^n \Rightarrow n = 1$$

50. (b): On doubling 'A' alone, rate of reaction increases 4 times so, the order w.r.t A is 2. On doubling 'B' alone, rate of reaction doesn't get altered, this means rate of reaction is independent of 'B'. So, the order w.r.t B is '0' order of reaction =  $2 + 0 = 2$ .



# Are you ready for Olympiads?

Exam on

18<sup>th</sup> Oct, 3<sup>rd</sup> Nov & 1<sup>st</sup> Dec 2022



## SYLLABUS\*

**Section – 1 :** Physics : Units and Measurements, Mechanics, Properties of Matter, Heat and Thermodynamics, Oscillations, Waves.

Chemistry : Some Basic Concepts of Chemistry, Structure of Atom, Classification of Elements and Periodicity in Properties, Chemical Bonding and Molecular Structure, States of Matter, Thermodynamics, Equilibrium, Redox Reactions, Hydrogen, The s-Block Elements, The p-Block Elements (Groups 13 and 14), Organic Chemistry - Some Basic Principles and Techniques, Hydrocarbons, Environmental Chemistry.

**Section – 2 :** Higher Order Thinking Questions - Syllabus as per Section – 1.

**Section – 3 :** Sets, Relations and Functions, Principle of Mathematical Induction, Logarithms, Complex Numbers & Quadratic Equations, Linear Inequalities, Sequences and Series, Trigonometry, Straight Lines, Conic Sections, Permutations and Combinations, Binomial Theorem, Statistics, Mathematical Reasoning, Limits and Derivatives, Probability, Introduction to 3-D Geometry.

## CLASS XI

Total Questions : 50

Time : 1 hr.

PATTERN & MARKING SCHEME			
Section	(1) Physics & Chemistry	(2) Achievers Section	(3) Mathematics or Biology
No. of Questions	25	5	20
Marks per Ques.	1	3	1

OR

**Section – 3 :** Diversity in the Living World, Structural Organisation in Plants and Animals, Cell : Structure and Functions, Plant Physiology, Human Physiology.

## Practice Questions

1. Solubility product constants ( $K_{sp}$ ) of three different types of salts at 25 °C are :

$$\begin{array}{ll} MX & : \quad 4 \times 10^{-8} \\ MX_2 & : \quad 3.2 \times 10^{-14} \\ M_3X & : \quad 2.7 \times 10^{-15} \end{array}$$

Which of the following represents the correct order of solubilities (mol dm<sup>-3</sup>) of these salts at 25 °C?

A.  $MX > MX_2 > M_3X$  B.  $M_3X > MX_2 > MX$   
C.  $MX_2 > M_3X > MX$  D.  $MX > M_3X > MX_2$

2. Which of the following statements are correct?

I. All molecules with polar bonds have dipole moment.  
II. When  $N_2$  changes to  $N_2^+$ , the N–N bond distance decreases while when  $O_2$  changes to  $O_2^+$  the O–O bond distance increases.  
III.  $N_2O$  and  $I_3^-$  are linear species.  
IV. In  $CaC_2$  molecule, two carbon atoms are held together by one  $\sigma$  bond and two  $\pi$  bonds.  
A. II and III only B. III and IV only  
C. II, III and IV only D. I, III and IV only

3. Identify the reducing agent and the oxidising agent in the reactions (i) and (ii) respectively.

(i)  $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$   
(ii)  $CuO + H_2 \rightarrow Cu + H_2O$   
A.  $MnO_2, H_2$  B.  $HCl, CuO$   
C.  $Cl_2, Cu$  D.  $MnCl_2, H_2O$

4. Calculate the wavelength of the photon that is emitted when an electron in Bohr orbit  $n = 2$  returns to the orbit  $n = 1$  in the hydrogen atom. The ionisation potential of hydrogen atom in ground state is  $2.17 \times 10^{-11}$  ergs per atom.

A. 3200 Å B. 1221 Å C. 1820 Å D. 1250 Å

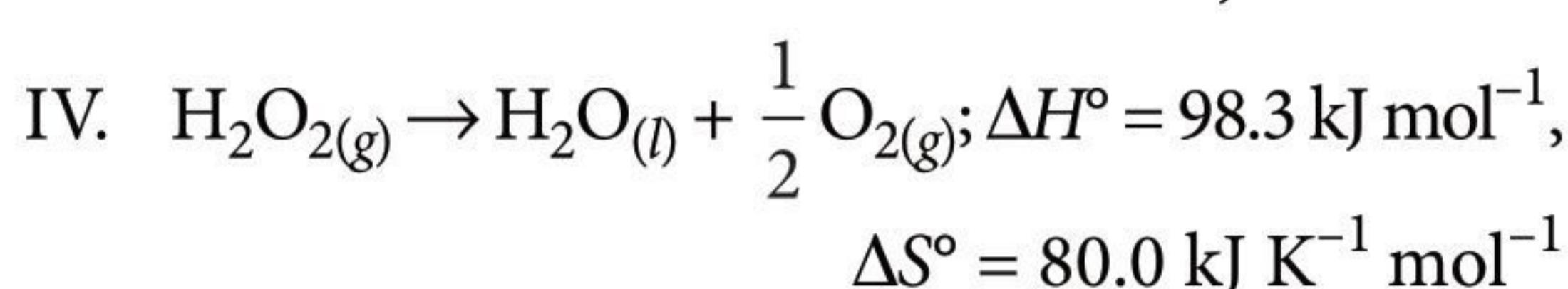
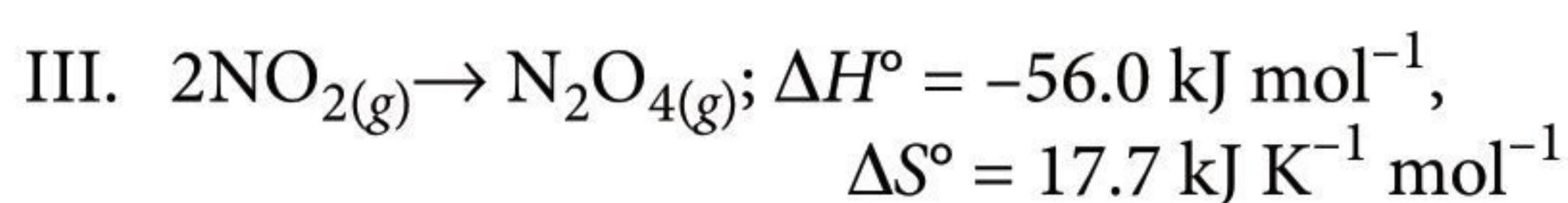
5. Study the given equilibrium system and select the correct statement(s).



I. On increasing the temperature, equilibrium mixture will have less [NO].  
II. On increasing the temperature, equilibrium constant remains unchanged.  
III. On increasing the pressure, equilibrium mixture will have more [NH<sub>3</sub>].  
IV. Addition of He at constant pressure promotes the oxidation of NH<sub>3</sub>.  
A. III and IV only B. II and III only  
C. I only D. I, III and IV only

6. Which of the following reactions is spontaneous at all temperatures?

I.  $H_{2(g)} \rightarrow 2H; \Delta H^\circ = 436 \text{ kJ mol}^{-1}, \Delta S^\circ = 90.7 \text{ kJ K}^{-1} \text{ mol}^{-1}$   
II.  $\frac{1}{2}N_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow NO_{(g)}; \Delta H^\circ = 90.3 \text{ kJ mol}^{-1}, \Delta S^\circ = 3.0 \text{ kJ K}^{-1} \text{ mol}^{-1}$



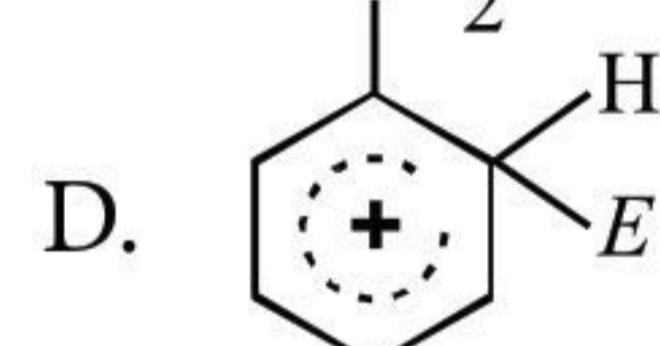
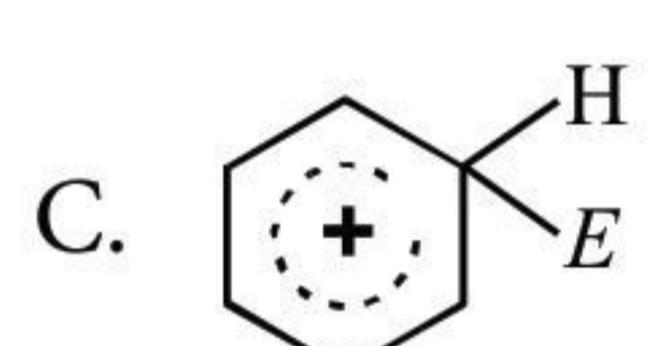
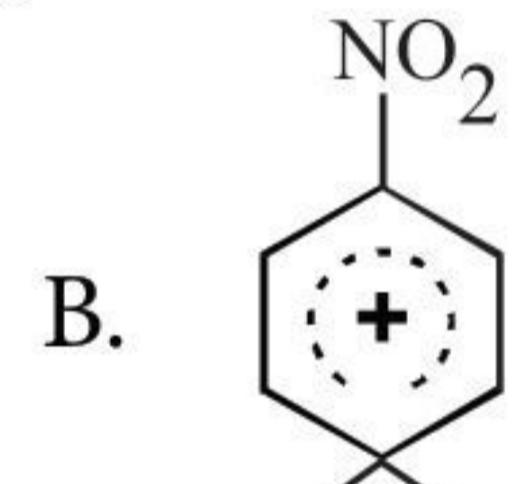
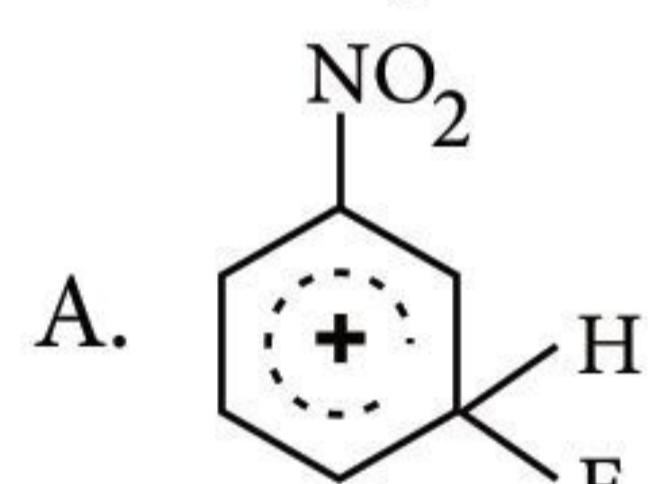
A. I and IV only      B. III only  
 C. II and IV only      D. None of these

7. Which of the following statements is/are correct?

I. The energy of an electron in  $3d$  orbital is less than that in  $4s$  orbital in the hydrogen atom.  
 II. The electron density in the  $xy$  plane in  $3d_{x^2-y^2}$  orbital is zero.  
 III. The magnetic quantum number can have a negative value.  
 IV. The number of radial nodes of  $3s$  and  $2p$  orbitals are 2 and 0 respectively.

A. II only      B. I, III and IV only  
 C. II and III only      D. I, II, III and IV

8. The electrophile,  $E^\oplus$  attacks the benzene ring to generate the intermediate  $\sigma$ -complex. Of the following, which  $\sigma$ -complex is of lowest energy?



9. In the given table, some of the elements of the periodic table with atomic numbers 3 to 18 are given. These are represented by letters which are not the usual symbols of the elements.

3	4	5	6	7	8	9	10
<i>a</i>				<i>e</i>		<i>g</i>	
11	12	13	14	15	16	17	18
<i>b</i>	<i>c</i>		<i>d</i>		<i>f</i>		

Among the given elements, the most electronegative element, a halogen, the most reactive alkali metal and an element with valency 4 are respectively

A. *e, f, b* and *d*      B. *a, f, c* and *g*  
 C. *g, f, a* and *e*      D. *f, f, a* and *d*.

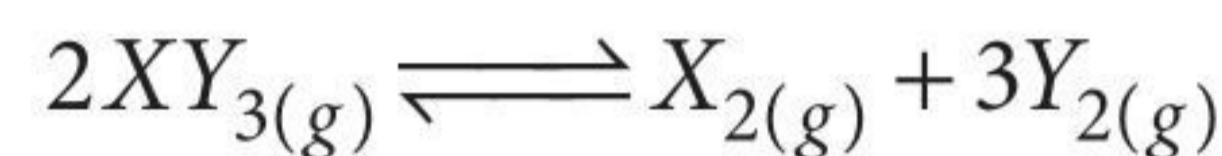
10. The first ( $\Delta_iH_1$ ) and second ( $\Delta_iH_2$ ) ionisation enthalpies (in  $\text{kJ mol}^{-1}$ ) and the electron gain enthalpy ( $\Delta_{eg}H$ ) (in  $\text{kJ mol}^{-1}$ ) of the elements I, II, III, IV and V are given:

Element	$\Delta_iH_1$	$\Delta_iH_2$	$\Delta_{eg}H$
I	520	7300	-60
II	419	3051	-48
III	1681	3374	-328
IV	1008	1846	-295
V	2372	5251	+48

Among these elements, the most reactive metal and the least reactive element are respectively

A. I and V      B. V and II  
 C. II and V      D. IV and V

11. 8 moles of a gas  $XY_3$  attain equilibrium in a closed container of volume  $1 \text{ dm}^3$  as,



If at equilibrium, 2 moles of  $X_2$  are present, then equilibrium constant is

A.  $36 \text{ mol}^2 \text{ L}^{-2}$       B.  $3 \text{ mol}^2 \text{ L}^{-2}$   
 C.  $27 \text{ mol}^2 \text{ L}^{-2}$       D.  $72 \text{ mol}^2 \text{ L}^{-2}$

12. If 0.212 g of an organic compound gave 0.406 g of  $\text{CO}_2$  and 0.249 g of  $\text{H}_2\text{O}$ , then the empirical formula of the compound is \_\_\_\_\_.

A.  $\text{CH}_3\text{O}$       B.  $\text{C}_2\text{H}_6\text{O}_2$   
 C.  $\text{C}_2\text{H}_6\text{O}$       D.  $\text{C}_3\text{H}_7\text{O}$

13. The given part of the modern periodic table shows positions of elements *a* to *j*.

<i>a</i>		<i>b</i>				<i>c</i>	<i>d</i>
<i>e</i>		<i>f</i>		<i>g</i>			
<i>h</i>		<i>i</i>	<i>j</i>	<i>g</i>			

Fill in the blanks by selecting an appropriate option. Element (i) resembles calcium in properties and element (ii) belongs to the same group as carbon. The formula of the hydride of *g* is (iii). The formula of compound formed between *b* and *c* is (iv) while the formula of compound formed between *e* and *g* is (v).

(i)	(ii)	(iii)	(iv)	(v)
A. <i>h</i>	<i>g</i>	$\text{Hg}$	$bc_2$	$e_2g$
B. <i>e</i>	<i>f</i>	$\text{H}_2g$	$bc_3$	$eg$
C. <i>b</i>	<i>j</i>	$\text{Hg}$	$b_2c$	$eg_2$
D. <i>e</i>	<i>f</i>	$\text{Hg}_2$	$bc$	$eg$

14. The best and latest technique for isolation, purification and separation of organic compounds is

A. crystallization      B. distillation  
 C. sublimation      D. chromatography.

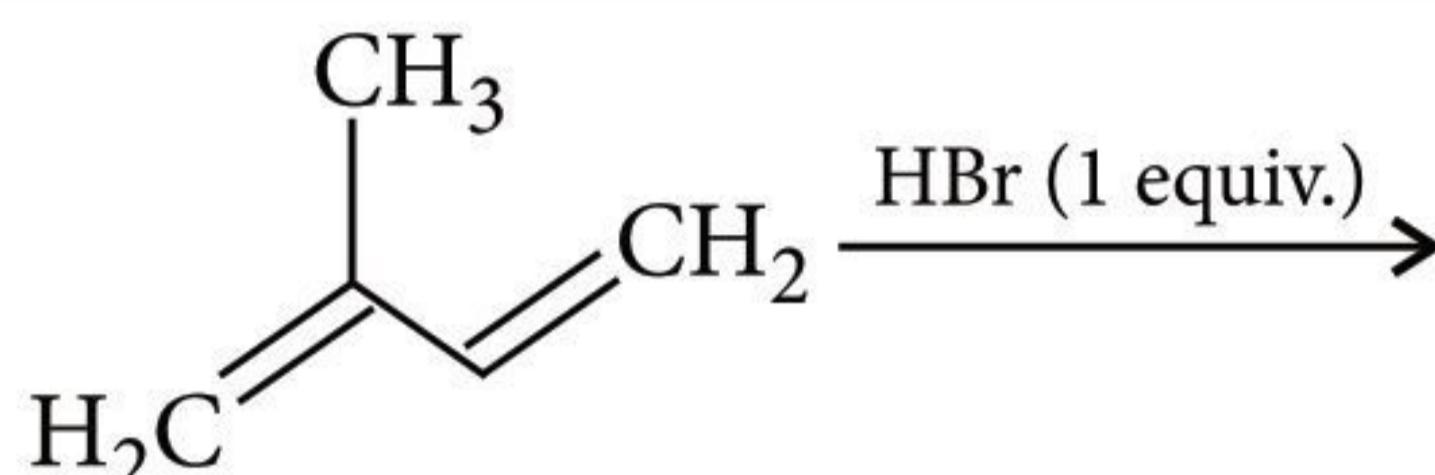
15. Which of the following statements is/are correct?

- $\text{CN}^-$  and  $\text{O}_2$  have same bond order and both are paramagnetic.
- Dissociation energy of  $\text{N}_2$  is greater than that of  $\text{N}_2^+$ .
- $\text{XeO}_3$  and  $\text{IO}_3^-$  are not isostructural species.
- $\text{BrF}_5$  and  $\text{SF}_4$  both have one lone pair of electrons.

A. II and IV only      B. I and III only  
C. II only      D. I, II, III and IV

### ACHIEVERS SECTION

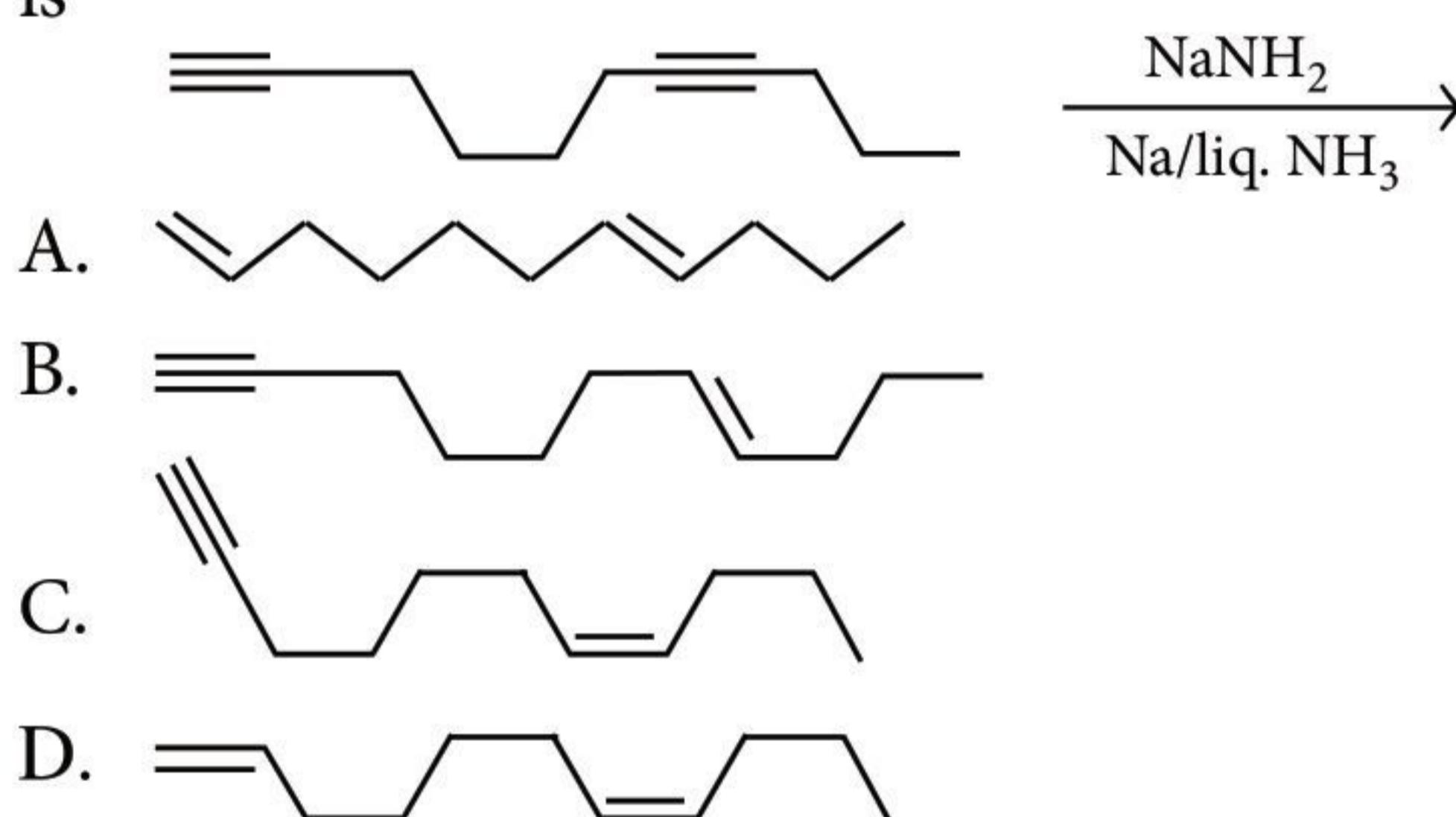
16.



The major product of the above reaction is

A.      B.   
C.      D.

17. The major product formed in the following reaction is



18. A few species are listed in the given box.

(i)  $\text{SO}_3$    (ii)  $\text{OSF}_2$    (iii)  $\text{SiO}_4^{4-}$    (iv)  $\text{BrF}_4^-$   
(v)  $\text{SF}_4$    (vi)  $[\text{Cu}(\text{NH}_3)_4]^{2+}$    (vii)  $[\text{FeCl}_4]^{2-}$

Now, read the given passage and fill in the blanks by choosing an appropriate option.

p have square planar shape while q have tetrahedral shape. r has/have  $sp^2$  hybridisation while s has/have  $sp^3d$  hybridisation.

	<b>p</b>	<b>q</b>	<b>r</b>	<b>s</b>
A.	iii, vii	iv, vi	i	v
B.	iv, vi	ii, iii, vii	i, iv	v, vii
C.	iv, vi	iii, vii	i	v
D.	iv, vii	iii, vi	iii	ii, iii

19. Some organic compounds are listed as :

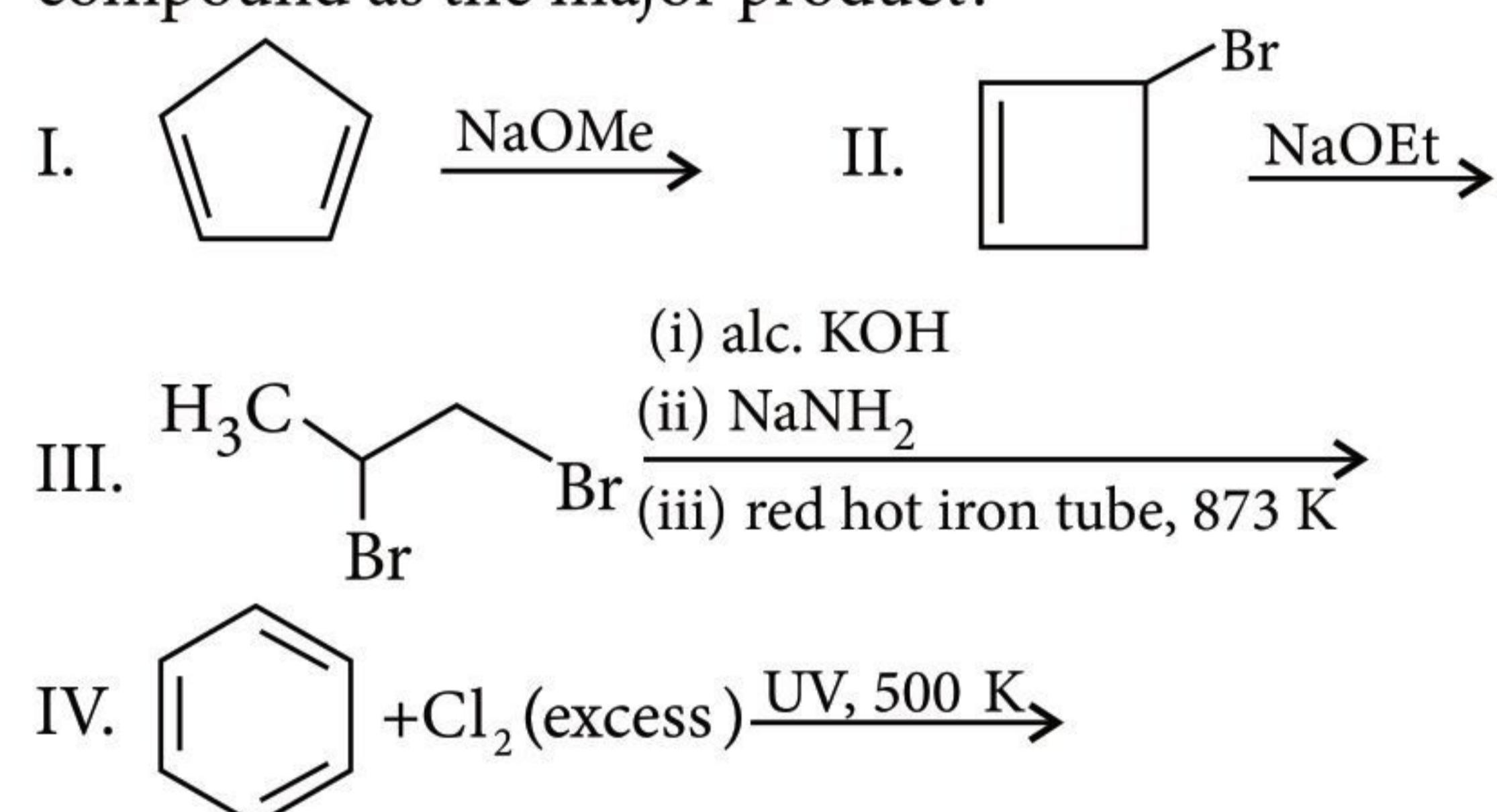
(i) 3-Ethylbromobenzene  
(ii) 1, 2, 3-Trimethylcyclopropane  
(iii) 4-ethyl bromobenzene  
(iv) Methoxybenzene  
(v) Cyclohexane  
(vi) 4-Methylphenol

Now, read the given passage and fill in the blanks by selecting an appropriate option.

(iv) and (vi) are x isomers, while (ii) and (v) are y isomers. (i) and (iii) are pairs of z isomers.

<b>x</b>	<b>y</b>	<b>z</b>
A. Functional	Positional	Chain
B. Chain	Functional	Positional
C. Functional	Chain	Positional
D. Positional	Functional	Chain

20. Which of the following reactions give aromatic compound as the major product?

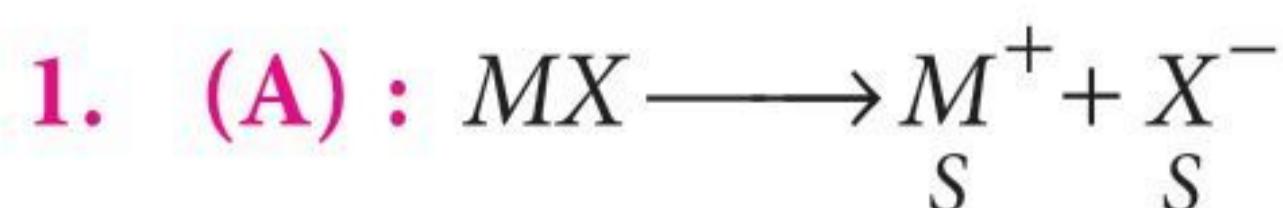


A. I, III and IV only      B. II and IV only  
C. I and III only      D. All the given reactions give aromatic compounds as the major product.

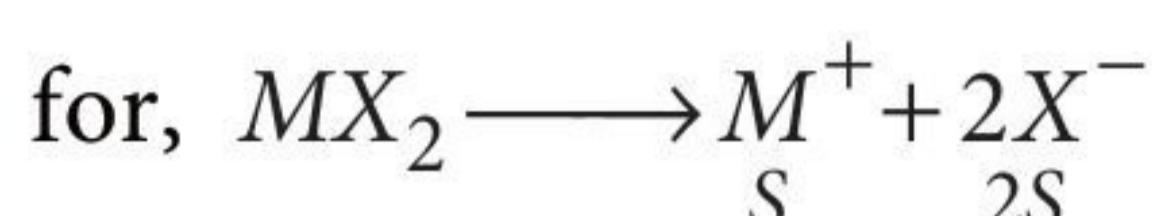
Darken your choice with HB Pencil

1.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	5.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	9.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	13.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	17.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D
2.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	6.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	10.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	14.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	18.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D
3.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	7.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	11.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	15.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	19.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D
4.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	8.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	12.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	16.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	20.	<input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D

## SOLUTIONS

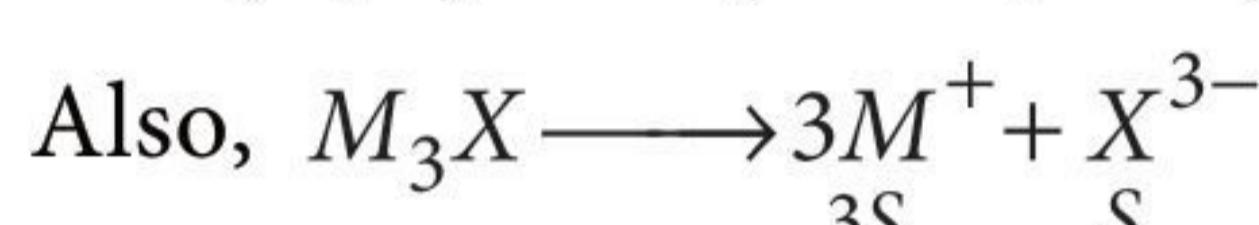


$$\text{Solubility } (S_1) \text{ of } MX = \sqrt{K_{sp}} = \sqrt{4 \times 10^{-8}} = 2 \times 10^{-4} \text{ M}$$



$$K_{sp} = (S)^1 (2S)^2 = 4S^3$$

$$S = \left( \frac{K_{sp}}{4} \right)^{\frac{1}{3}} = \left( \frac{3.2 \times 10^{-14}}{4} \right)^{\frac{1}{3}} = 2 \times 10^{-5} \text{ M}$$



$$K_{sp} = (3S)^3 S^1 = 27S^4$$

$$S = \left( \frac{2.7 \times 10^{-15}}{27} \right)^{\frac{1}{4}} = (10^{-16})^{\frac{1}{4}} = 10^{-4} \text{ M}$$

Hence, the correct order of solubility is:



2. (B) : All the molecules with polar bonds do not have dipole moment. Sometimes due to regular shape, dipole moment vectors cancel out each other and the molecule becomes non-polar.

When  $N_2$  changes to  $N_2^+$ , the N—N bond length or distance increases as the bond order decreases from 3 to 2.5 during this conversion. When  $O_2$  changes to  $O_2^+$ , the bond order increases from 2 to 2.5, which suggests a decrease in O—O bond distance.

Rest two statements are correct as  $N_2O$  and  $I_3^-$  are linear species and in  $CaC_2$ , the  $Ca^{2+}$  ion is bonded to  $C_2^{2-}$  anion,  $[:C \equiv C:]^{2-}$  has 1 sigma and 2 pi bonds.

3. (B) : In reaction (i) HCl is the reducing agent as it itself gets oxidised to  $Cl_2$ . In reaction (ii), CuO is the oxidising agent as it itself gets reduced to Cu.

$$4. (B) : \Delta E = E_2 - E_1 = 2.17 \times 10^{-11} \left[ \frac{1}{n_1^2} - \frac{1}{n_2^2} \right] \\ = 2.17 \times 10^{-11} \left[ \frac{1}{2^2} - \frac{1}{1^2} \right] = -2.17 \times 10^{-11} \times \frac{3}{4} \text{ erg}$$

$$\text{Also, } \Delta E = E_2 - E_1 = h\nu = \frac{hc}{\lambda}$$

$$\Rightarrow \lambda = \frac{hc}{\Delta E} = \frac{6.62 \times 10^{-27} \text{ erg} \times 3.0 \times 10^{10} \text{ cm}}{2.17 \times 10^{-11} \times 3/4 \text{ erg}} \\ = 12.2027 \times 10^{-6} \text{ cm} \text{ or } 1220.27 \text{ } \text{\AA} \approx 1221 \text{ } \text{\AA}$$

5. (D)

6. (B) : The Gibbs free energy for a reaction is determined using the following equation.

$$\Delta G = \Delta H - T\Delta S$$

For a reaction to be spontaneous, the change in Gibbs free energy should be negative. From the above equation, it is clear that for  $\Delta G$  to be negative (at all temperatures),  $\Delta H$  must be negative and  $\Delta S$  must be positive.

7. (B) : Since no electrons are present in the  $3d$  and  $4s$  orbitals of H-atom, greater the value of  $n$ , larger is the energy. For a  $4s$ -orbital,  $n = 4$ , and for a  $3d$  orbital,  $n = 3$ . The electron density is not zero in the  $xy$  plane in  $3d_{x^2-y^2}$  orbital as the orbital lobes of the  $3d_{x^2-y^2}$  orbital are along the  $x$  and  $y$ -axis. The magnetic quantum number ( $m_l$ ) can have negative values as for a  $p$ -subshell,  $m_l$  values are  $-1, 0$  and  $+1$ .

Number of radial nodes =  $n - l - 1$

For a  $3s$ -orbital, number of radial nodes =  $3 - 0 - 1 = 2$

For a  $2p$ -orbital, number of radial nodes =  $2 - 1 - 1 = 0$

8. (C)

9. (A) : Among the given elements,  $e$  (atomic number = 8) is the most electronegative element as  $e$  represents oxygen.  $f$  (atomic number = 17) is a halogen that belongs to group VII A. Alkali metals are highly reactive due to large size and low ionization energies. Hence  $b$  (atomic number = 11), represents sodium which is the most reactive. Element  $d$  (atomic number = 14) represents silicon, a group IV A element, whose valency is 4.



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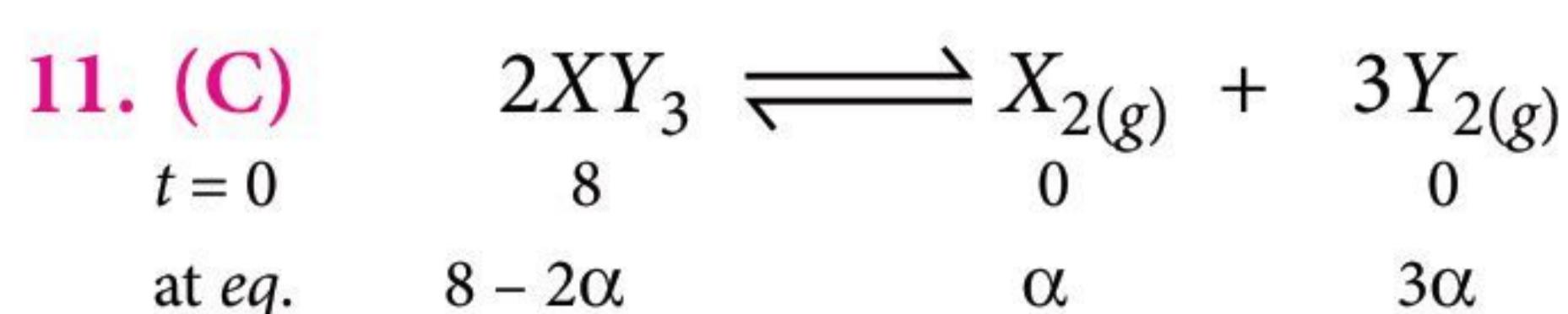


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10. (C)



$$\text{Thus, } K_c = \frac{[X_2][Y_2]^3}{[XY_3]^2}$$

Given,  $[X_2] = 2$  moles  $\Rightarrow \alpha = 2$

$$\therefore [XY_3] = \frac{4}{1}; [X_2] = \frac{2}{1}; [Y_2] = \frac{6}{1}$$

$$\text{Hence, } K_c = \frac{2 \times 6^3}{4^2} = 27 \text{ mol}^2 \text{L}^{-2}$$

12. (C) : Mass of organic compound = 0.212 g

Mass of  $\text{CO}_2$  = 0.406 g

Mass of  $\text{H}_2\text{O}$  = 0.249 g

$$\% \text{ C} = \frac{12}{44} \times \frac{0.406 \text{ g}}{0.212 \text{ g}} \times 100 = 52.22\%$$

$$\% \text{ H} = \frac{2}{18} \times \frac{0.249 \text{ g}}{0.212 \text{ g}} \times 100 = 13.05\%$$

Now % of O =  $100 - 52.22 - 13.05 = 34.73\%$

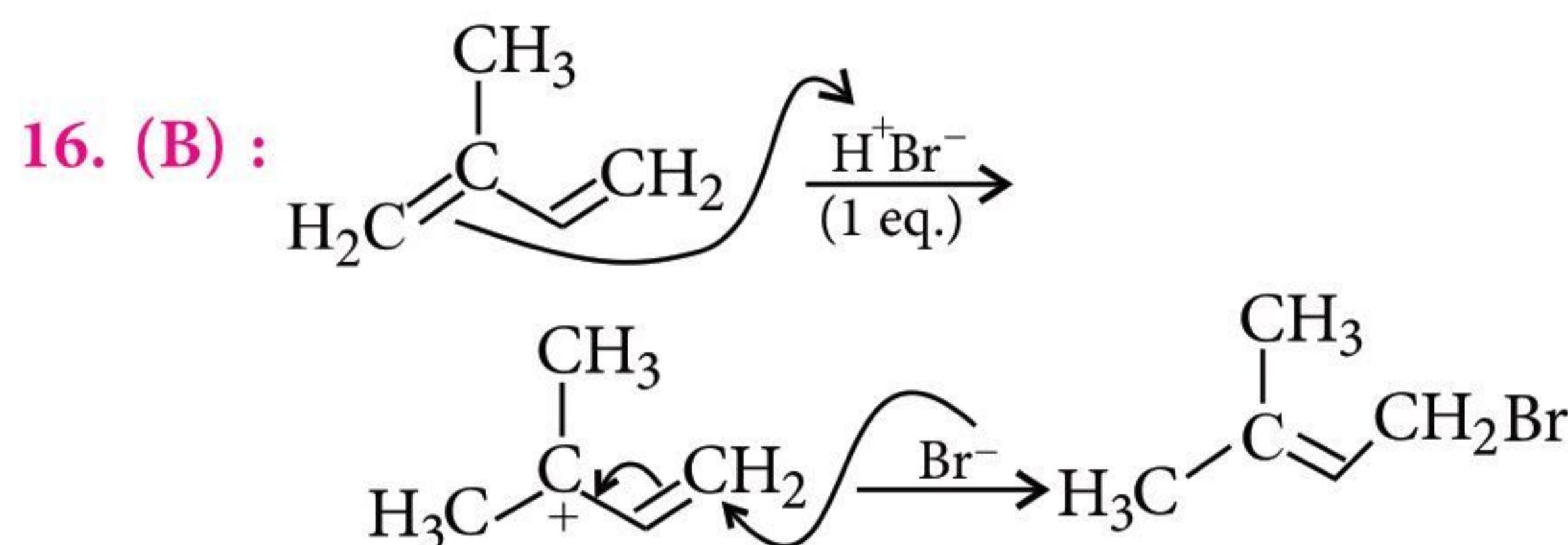
S. No.	Element	%	At. wt.	Relative no. of moles	Simple ratio
1	C	52.22	12	$\frac{52.25}{12} = 4.35$	$\frac{4.35}{2.17} = 2.00$
2	H	13.05	1	$\frac{13.05}{1} = 13.05$	$\frac{13.05}{2.17} = 6.01$
3	O	34.73	16	$\frac{34.73}{16} = 2.17$	$\frac{2.17}{2.17} = 1$

Thus, the empirical formula of compound is  $\text{C}_2\text{H}_6\text{O}$ .

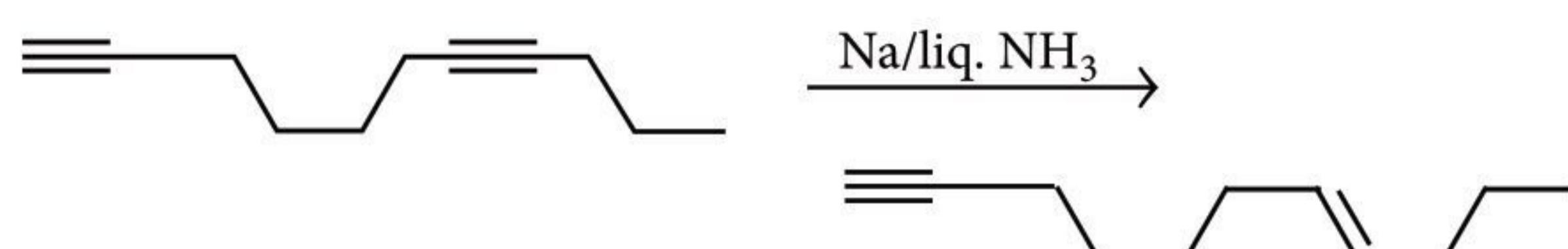
13. (B)

14. (D) : Chromatography is a technique based on differential migration. Thus, it is used for isolation, purification and separation of organic compounds.

15. (A)



17. (B) : *Trans* addition of  $\text{H}_2$  takes place with  $\text{Na}/\text{liq. NH}_3$ . i.e., Birch reduction, but terminal alkynes cannot be reduced by Birch reduction.

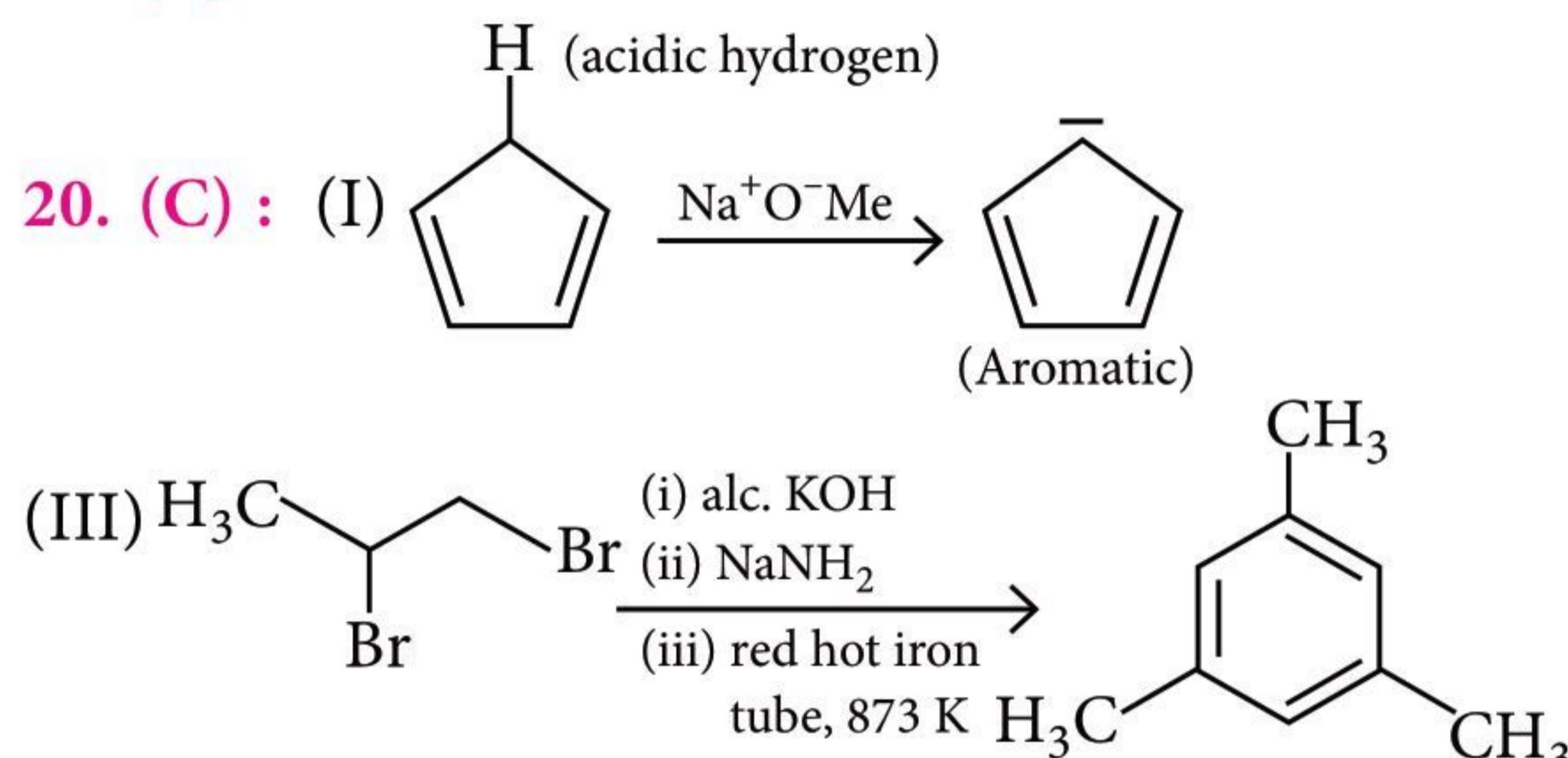


18. (C) : In the ion  $\text{BrF}_4^-$ , the central atom Br has four bond pairs and two lone pair of electrons. This suggests that its steric number is equal to 6. According to VSEPR theory, the molecular geometry will be square planar as it is  $\text{AX}_4\text{E}_2$  type.  $[\text{Cu}(\text{NH}_3)_4]^{2+}$  has a square planar shape and the Cu is  $sp^2\text{d}$  hybridised.  $\text{SiO}_4^{4-}$  and  $[\text{FeCl}_4]^{2-}$  have a tetrahedral shape. In case of  $\text{SF}_4$ , the hybridisation of S can be determined as shown:

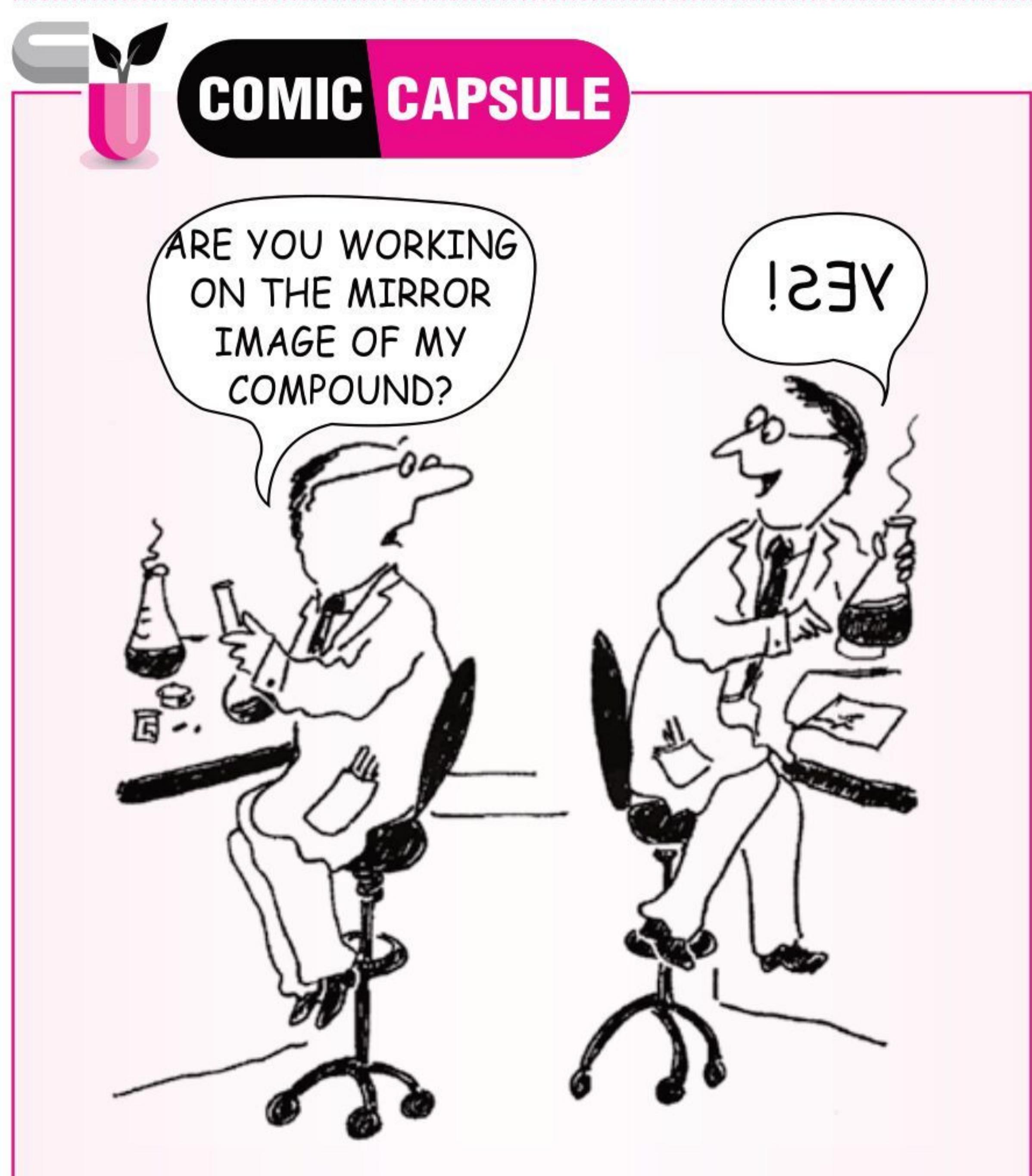
$$\text{Hybridisation} = \frac{1}{2}(6+4) = \frac{10}{2} = 5$$

Hence, the hybridisation is  $sp^3\text{d}$ .

19. (C)



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Exam on

18<sup>th</sup> Oct, 3<sup>rd</sup> Nov & 1<sup>st</sup> Dec 2022



## SYLLABUS\*

**Section – 1 :** Physics : Electricity and Magnetism, Electromagnetic Induction, Alternating current, Electromagnetic waves, Optics, Modern Physics, Semiconductor Electronics, Communication Systems.

**Chemistry :** Solid State, Solutions, Electrochemistry, Chemical Kinetics, Surface Chemistry, General Principles and Processes of Isolation of Elements, *p*-Block Elements (Group 15 to 18), *d*- & *f*-Block Elements, Coordination Compounds, Haloalkanes and Haloarenes, Alcohols, Phenols and Ethers, Aldehydes, Ketones and Carboxylic Acids, Amines, Biomolecules, Polymers, Chemistry in Everyday Life.

**Section – 2 :** Higher Order Thinking Questions - Syllabus as per Section – 1.

**Section – 3 :** Relations and Functions, Inverse Trigonometric Functions, Matrices and Determinants, Continuity and Differentiability, Application of Derivatives, Integrals, Application of Integrals, Differential Equations, Vector Algebra, Three Dimensional Geometry, Probability, Linear Programming.

## CLASS XII

Total Questions : 50

Time : 1 hr.

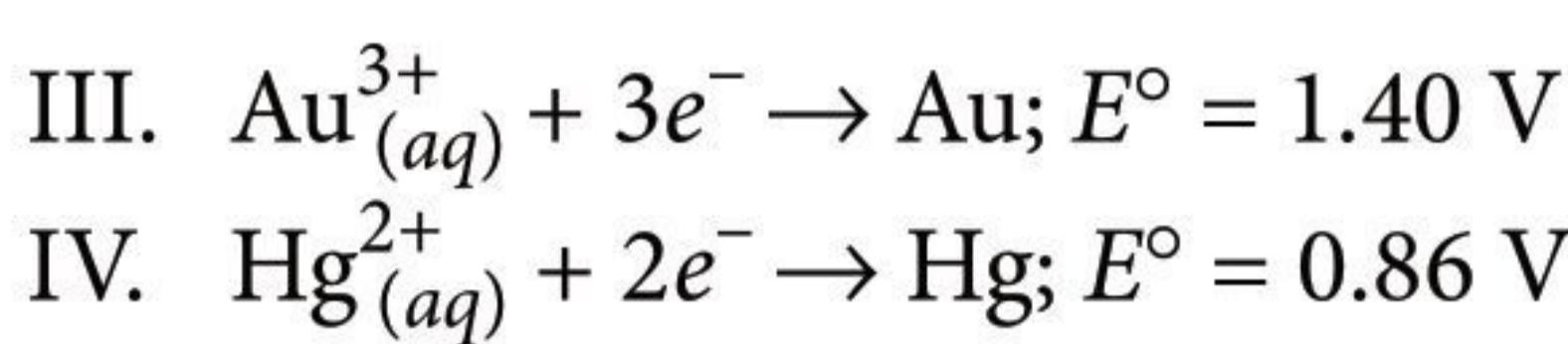
PATTERN & MARKING SCHEME			
Section	(1) Physics & Chemistry	(2) Achievers Section	(3) Mathematics or Biology
No. of Questions	25	5	20
Marks per Ques.	1	3	1

OR

**Section – 3 :** Reproduction, Genetics and Evolution, Biology in Human Welfare, Biotechnology, Ecology.

## Practice Questions

- Which of the following compounds is least reactive towards nucleophilic substitution ( $S_N2$ ) reaction?
  - $CH_2=CH-CH_2Cl$
  - $CH_3-C(CH_3)_2-Cl$
  - 
  - $CH_3CH(Cl)CH_3$
- Identify the incorrect statements from the following.
  - $[Co(en)_2Cl_2]^+$  has four optical isomers.
  - The IUPAC nomenclature of  $K_2[Cr(NO)(NH_3)(CN)_4]$  is potassium amminetetracyanidonitrosyl chromate(I).
  - $[CuN(CH_3)_4]^+[BF_4]^-$  is coloured due to *d-d* transition.
  - $[Mn(CN)_6]^{4-}$  is outer-orbital complex with  $sp^3d^2$  hybridisation and is paramagnetic.
  - I, III and IV only
  - II and III only
  - I and IV only
  - I, II, III and IV
- Consider the following ions :
  - $Ni^{2+}$
  - $Co^{2+}$
  - $Cr^{2+}$
  - $Fe^{3+}$
 The correct order of magnetic moments of these ions is
  - $IV > III > II > I$
  - $II > III > IV > I$
  - $II < IV < III < I$
  - $III < I < II < IV$
- Which of the following alcohols shows fastest reaction with HI?
  - 
  - 
  - 
  -
- For the given compounds I, II, III, IV :
  - 
  - $CH_3CH_2NH_2$
  - 
  -
- Select the correct statement.
  - II is less basic than I.
  - I is more basic than rest of three.
  - I is more acidic than III and IV.
  - III is more acidic than I and II.
- $E^\circ$  values for some metal ions are :
  - $Zn^{2+}_{(aq)} + 2e^- \rightarrow Zn; E^\circ = -0.76\text{ V}$
  - $Cd^{2+}_{(aq)} + 2e^- \rightarrow Cd; E^\circ = -0.40\text{ V}$



Which of the following metals cannot be oxidised by  $\text{NO}_3^-$  ion in aqueous solution?

(Given:  $E^\circ_{\text{NO}_3^-/\text{NO}} = 0.97 \text{ V}$ )

A. III and IV only      B. I and II only  
 C. III only      D. I only

7. Phenol associates in benzene to a certain extent to form a dimer. A solution containing 20 g of phenol in 1.0 kg of benzene has its freezing point lowered by 0.69 K. Calculate the fraction of phenol that has dimerised.

(Given:  $K_f$  for benzene = 5.1 K m<sup>-1</sup>)

A. 50%      B. 73%      C. 95%      D. 63.5%

8. Find the incorrect match(es).

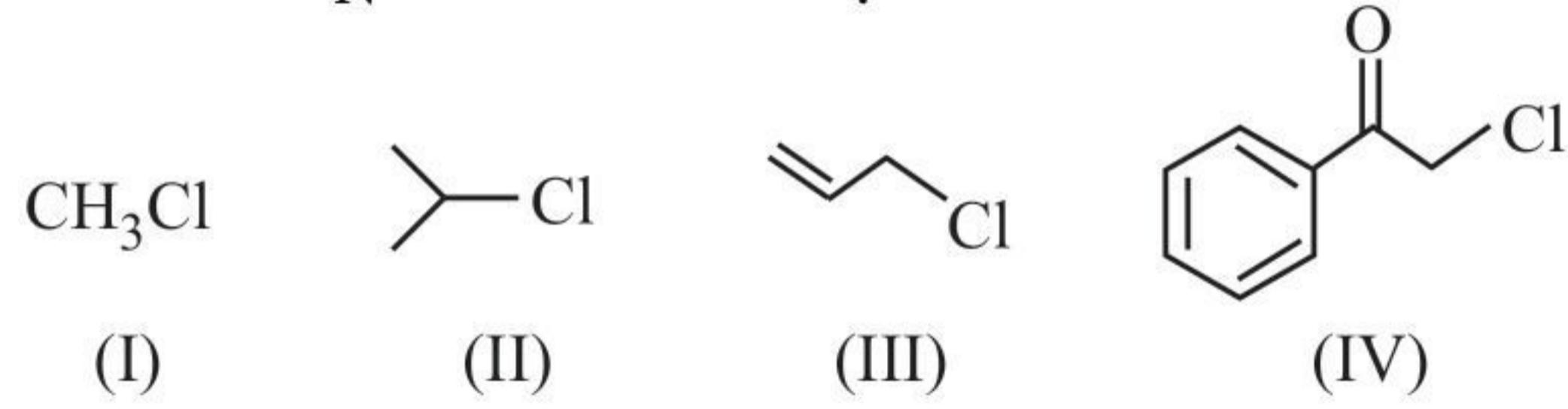
I.  $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]^+$  – Optical isomerism  
 II.  $[\text{Fe}(\text{CN})_6]^{3-}$  –  $d^2sp^3$  hybridisation  
 III.  $[\text{Zn}(\text{NH}_3)_6]^{2+}$  – Outer orbital complex  
 IV.  $[\text{Cu}(\text{NH}_3)_4]^{2+}$  – Tetrahedral and 1.73 BM

A. II and III only      B. I and IV only  
 C. I only      D. IV only

9. *p*-Nitrophenol is subjected to reduction, diazotisation and hydrolysis in sequence. The final product formed is

A. 1, 4-Benzoquinone      B. *p*-Cresol  
 C. Hydroquinone      D. None of these.

10. The rates of reactivity of following compounds towards  $S_N2$  reactions vary as



A. I > II > III > IV      B. IV > I > III > II  
 C. I > III > II > IV      D. III > I > IV > II

11. Which of the following statements are incorrect?

I. Specific conductance increases with dilution.  
 II. Equivalent conductance decreases with dilution.  
 III. The conductance of all electrolytes increases with increase in temperature.  
 A. I and II only      B. I and III only  
 C. II and III only      D. I, II and III

12. Select the incorrect statement.

A. Crystal field stabilisation energy of  $d^2$  configuration in an octahedral complex of a weak field ligand is  $-0.8\Delta_o$ .  
 B.  $[\text{MnF}_6]^{4-}$  is an example of a coordination compound having weak field ligand and  $d^5$  configuration.

C. Effective atomic number of Pt in  $[\text{PtCl}_6]^{2-}$  is 84.  
 D. Geometrical isomerism is shown by  $[\text{Pt}(\text{NH}_3)_4\text{Cl}_2]$ .

13. An electric current was passed through an aqueous solution of a mixture of alanine, glutamic acid and arginine buffered at pH 6. Which of the following observations is correct if isoelectric points of alanine, glutamic acid and arginine are 6, 3.2 and 10.7 respectively?

A. Glutamic acid migrates to anode, arginine migrates to cathode and alanine remains uniformly distributed in solution.  
 B. Glutamic acid migrates to cathode while alanine and arginine remain uniformly distributed in solution.  
 C. Alanine, arginine and glutamic acid, all three remain uniformly distributed in solution.  
 D. All three move to cathode.

14. In the following reaction, the initial concentrations of the reactant and initial rate at 298 K are given:

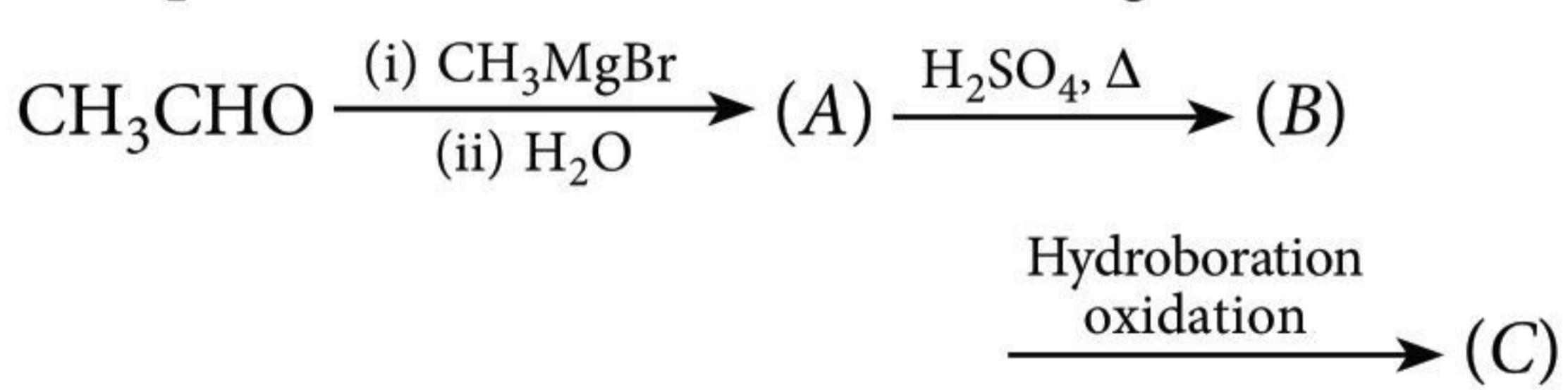


$[A]_0, \text{ mol L}^{-1}$	Initial rate in $\text{mol L}^{-1} \text{ s}^{-1}$
0.01	$5.0 \times 10^{-5}$
0.02	$2.0 \times 10^{-4}$

The value of rate constant of this reaction at 298 K is

A.  $0.01 \text{ s}^{-1}$       B.  $5 \times 10^{-3} \text{ mol L}^{-1} \text{ s}^{-1}$   
 C.  $2.0 \times 10^{-2} \text{ mol L}^{-1} \text{ s}^{-1}$   
 D.  $5 \times 10^{-1} \text{ mol}^{-1} \text{ L s}^{-1}$

15. Compounds A and C in the following reaction are



A. identical      B. positional isomers  
 C. optical isomers      D. functional isomers.

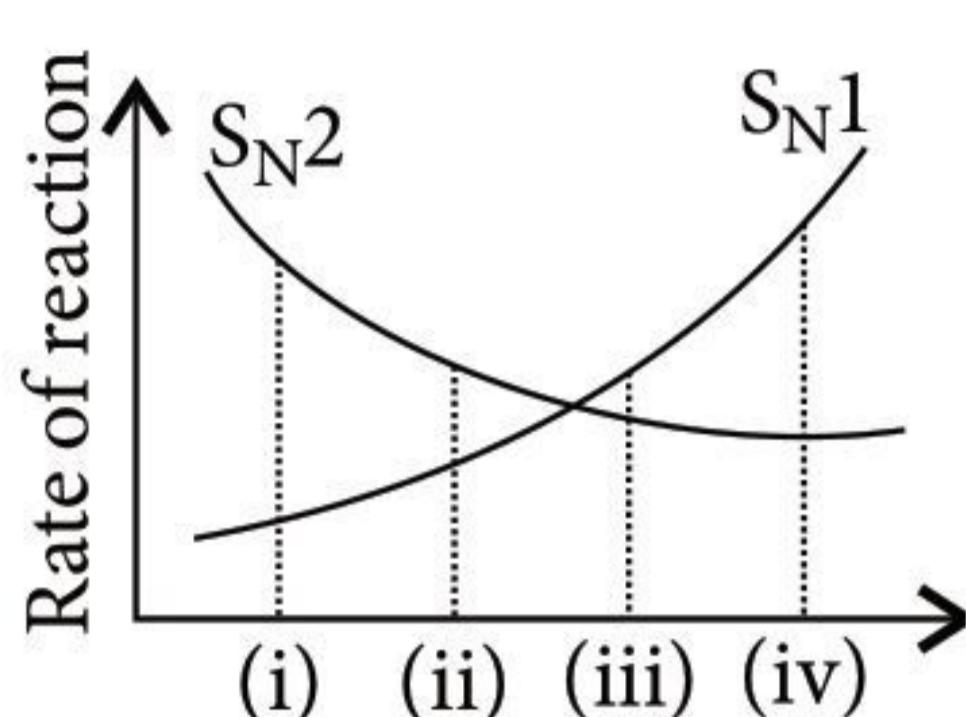
### ACHIEVERS SECTION

16. Read the given paragraph carefully and fill in the blanks by selecting an appropriate option.

An organic compound (P) on treatment with acetic acid in the presence of sulphuric acid produces an ester (Q). (P) on mild oxidation, gives (R). (R) with 50% potassium hydroxide followed by acidification with dilute hydrochloric acid generates (P) and (S). (S) with phosphorus pentachloride followed by reaction with ammonia gives (T) and (T) on dehydration produces hydrocyanic acid.

<b>P</b>	<b>Q</b>	<b>R</b>	<b>S</b>	<b>T</b>
A. $\text{C}_2\text{H}_5\text{OH}$	$\text{CH}_3\text{COOC}_2\text{H}_5$	$\text{CH}_3\text{CHO}$	$\text{CH}_3\text{COOH}$	$\text{CH}_3\text{CONH}_2$
B. $\text{CH}_3\text{OH}$	$\text{HCOOCH}_3$	$\text{CH}_3\text{COCH}_3$	$\text{HCOOH}$	$\text{HCONH}_2$
C. $(\text{CH}_3)_3\text{COH}$	$\text{HCOOCH}_3$	$\text{HCHO}$	$\text{C}_2\text{H}_5\text{COOH}$	$\text{C}_2\text{H}_5\text{CONH}_2$
D. $\text{CH}_3\text{OH}$	$\text{CH}_3\text{COOCH}_3$	$\text{HCHO}$	$\text{HCOOH}$	$\text{HCONH}_2$

17. The given curves show the rates of nucleophilic substitution reactions for different types of halides. Which of the following best represents (i), (ii), (iii) and (iv)?

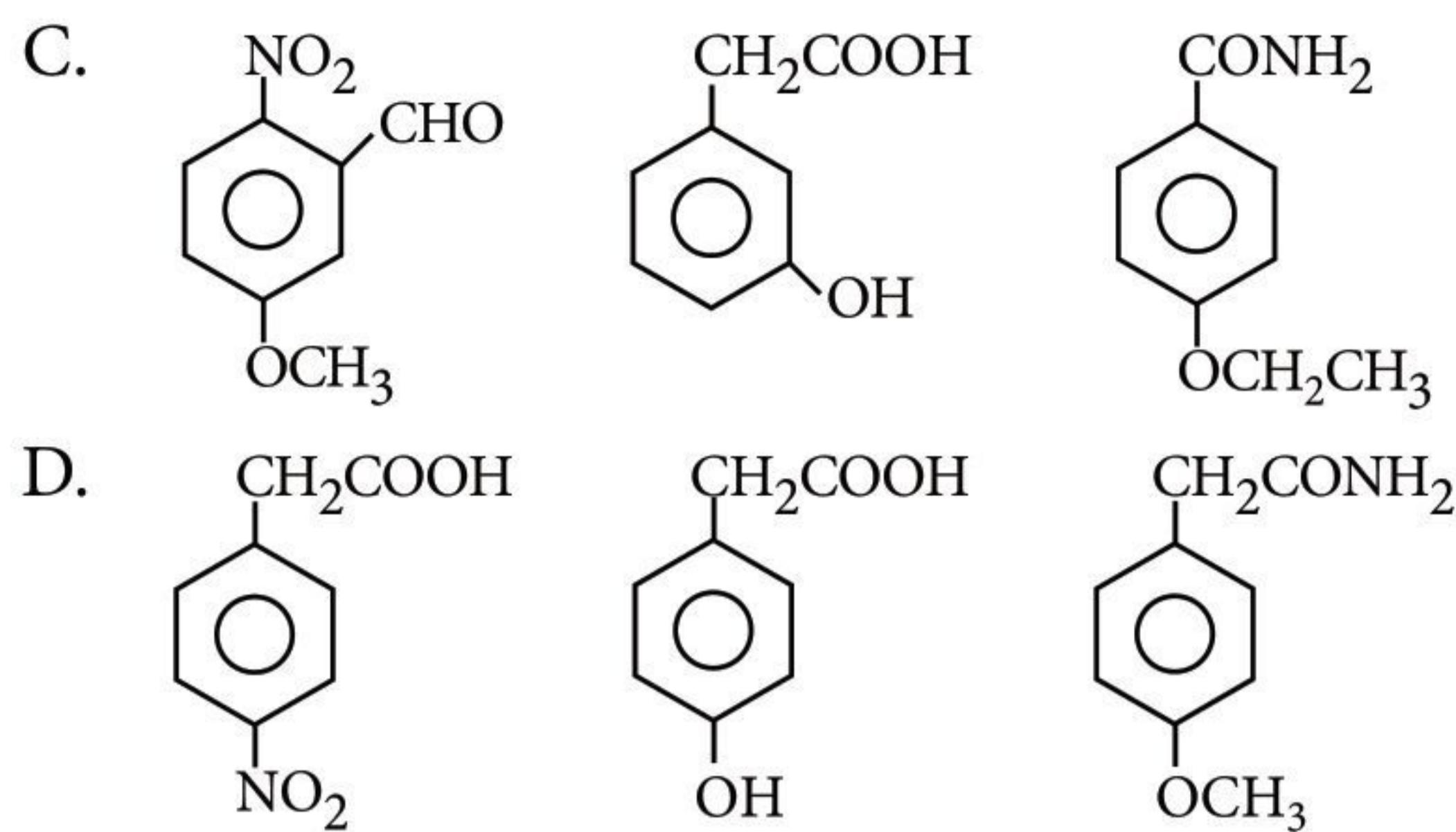
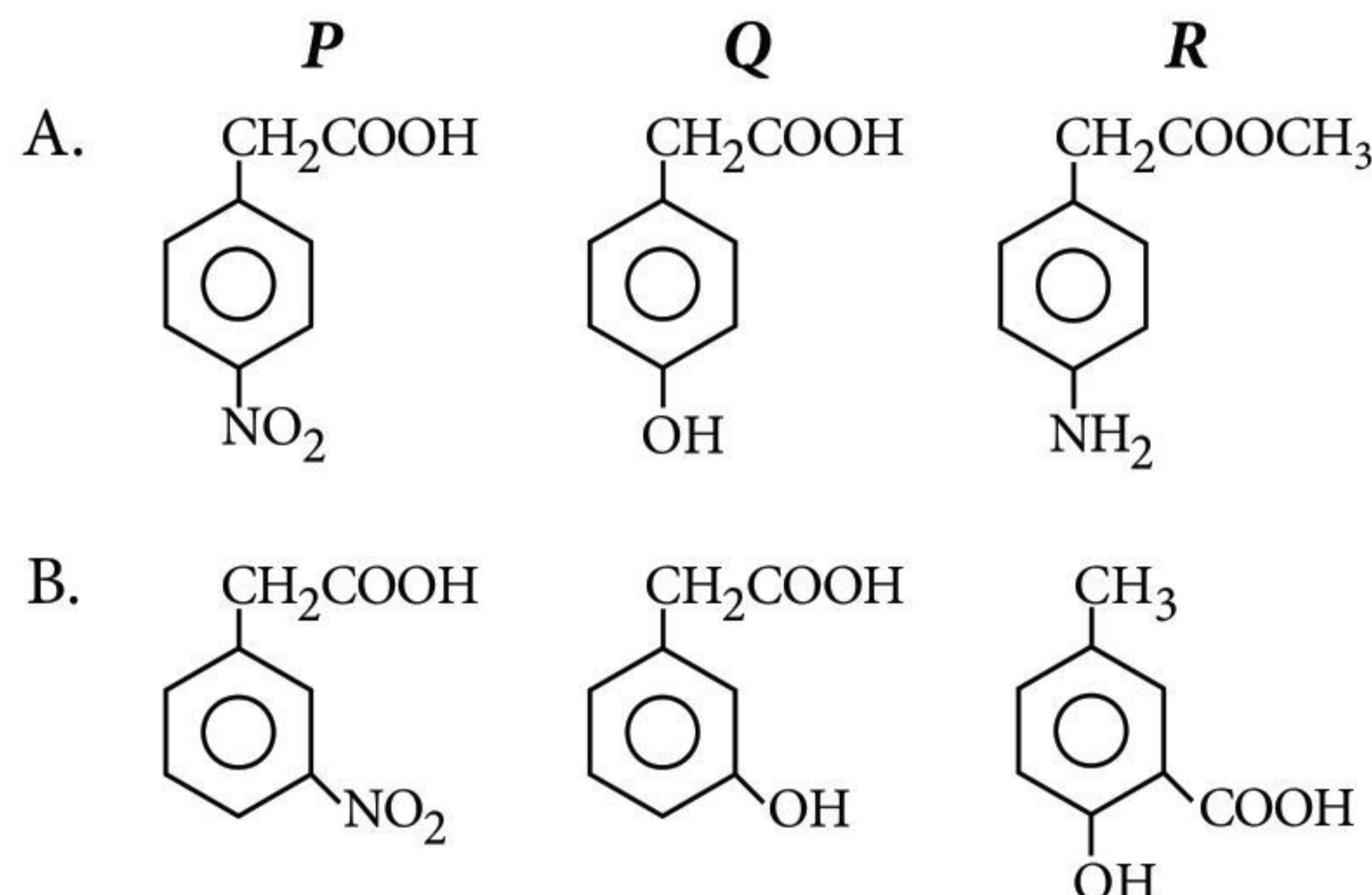
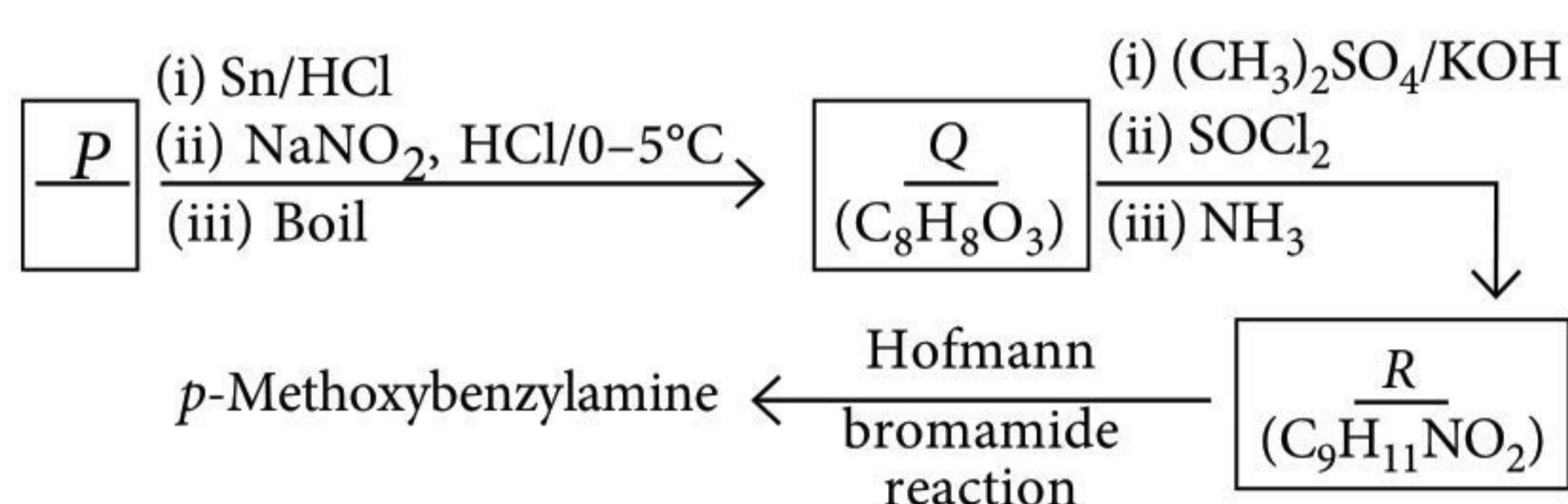


(i) (ii) (iii) (iv)

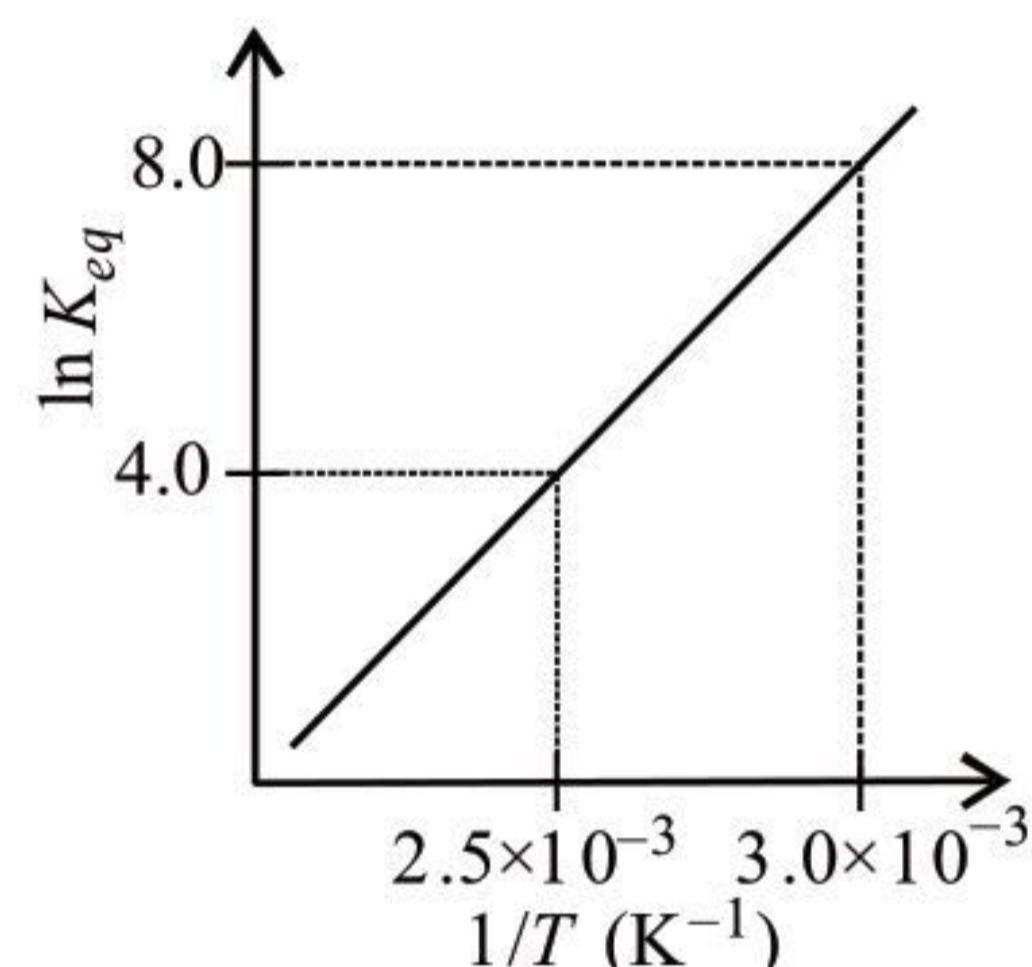
A.  $(\text{CH}_3)_2\text{C}=\text{CHCH}_2\text{Cl}$   $(\text{CH}_3)_3\text{CCl}$   $\text{C}_6\text{H}_5\text{CH}=\text{CHCH}_2\text{Cl}$   $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$   
 B.  $\text{C}_6\text{H}_5\text{COCH}_2\text{Cl}$   $\text{C}_6\text{H}_5\text{CH}_2\text{Cl}$   $\text{CH}_2=\text{CHCH}_2\text{Cl}$   $(\text{CH}_3)_2\text{CHCl}$   
 C.  $\text{CH}_3\text{Cl}$   $\text{CH}_3\text{CH}_2\text{Cl}$   $(\text{CH}_3)_2\text{CHCl}$   $(\text{CH}_3)_3\text{CCl}$   
 D. None of these

18. Read the given passage and fill in the blanks by selecting an appropriate option.

An aromatic compound (P) having molecular formula,  $\text{C}_8\text{H}_7\text{NO}_4$  undergoes the following sequence of reactions :



19. A plot of  $\ln K_{eq}$  versus inverse of temperature for a reaction is shown in the given graph (not drawn to scale).



A. The reaction is endothermic with negligible enthalpy change.  
 B. The reaction is endothermic.  
 C. The reaction is exothermic.  
 D. The reaction can be either exothermic or endothermic depending upon the activation energy.

20. Following expressions (i) - (vi) are given for reactions of different orders.

(i)  $t_{50} = \frac{\ln 2}{k}$  (ii)  $-\frac{d[A]}{dt} = k[A]$   
 (iii)  $-\frac{d[A]}{dt} = k[A]^2$  (iv)  $[A] = -kt + [A]_0$   
 (v)  $t_{50} = \frac{[A]_0}{2k}$  (vi)  $\ln[A] = -kt + \ln[A]_0$

Select the correct match.

<b>Zero order</b>	<b>First order</b>	<b>Second order</b>
A. (iv)	(ii) and (v)	(i), (iii) and (vi)
B. (iv) and (v)	(iii)	(i), (ii) and (vi)
C. (iv) and (v)	(i), (ii) and (vi)	(iii)
D. (i) and (iii)	(iv) and (v)	(ii) and (vi)

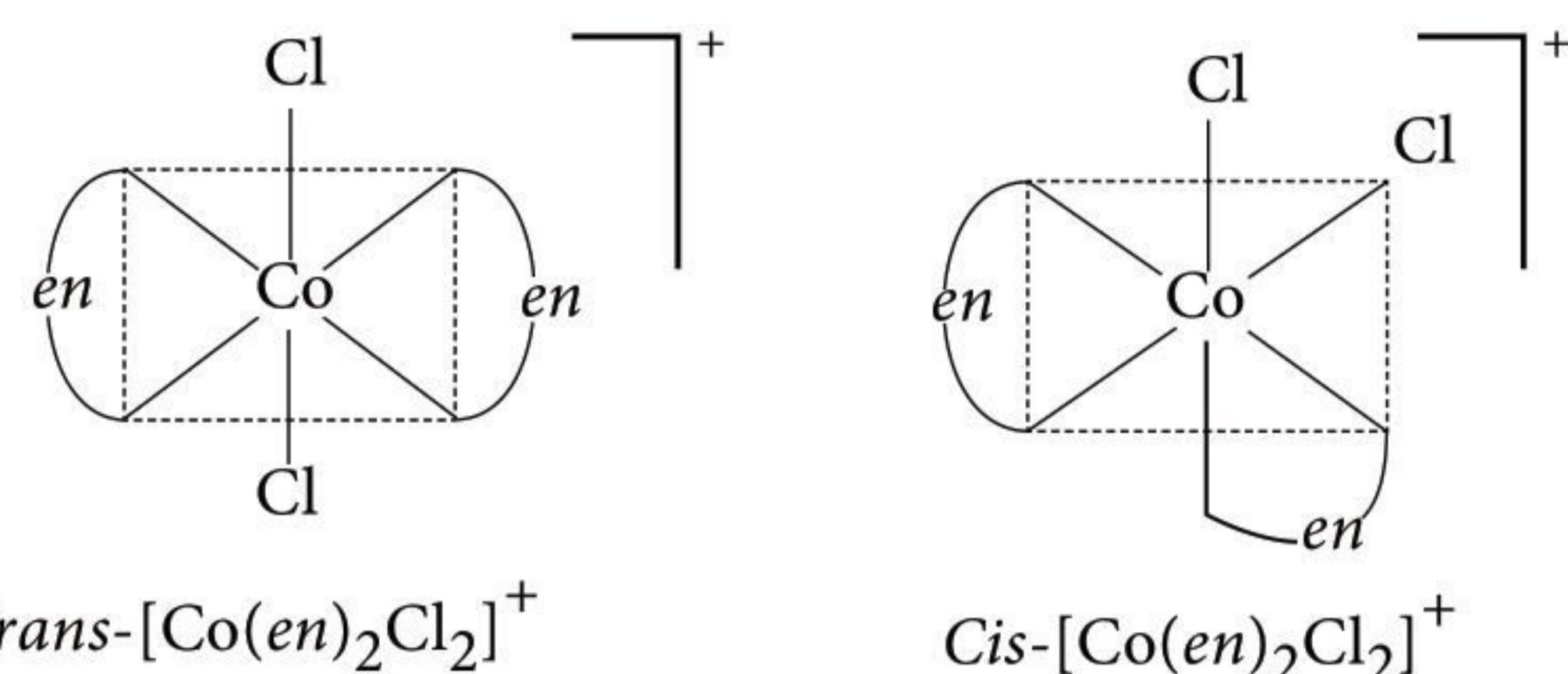
Darken your choice with HB Pencil

1. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	5. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	9. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	13. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	17. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D
2. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	6. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	10. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	14. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	18. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D
3. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	7. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	11. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	15. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	19. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D
4. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	8. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	12. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	16. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D	20. <input type="radio"/> A <input type="radio"/> B <input type="radio"/> C <input type="radio"/> D

## SOLUTIONS

1. (C)

2. (A) :  $[\text{Co}(\text{en})_2\text{Cl}_2]^+$  has three optical isomers as shown

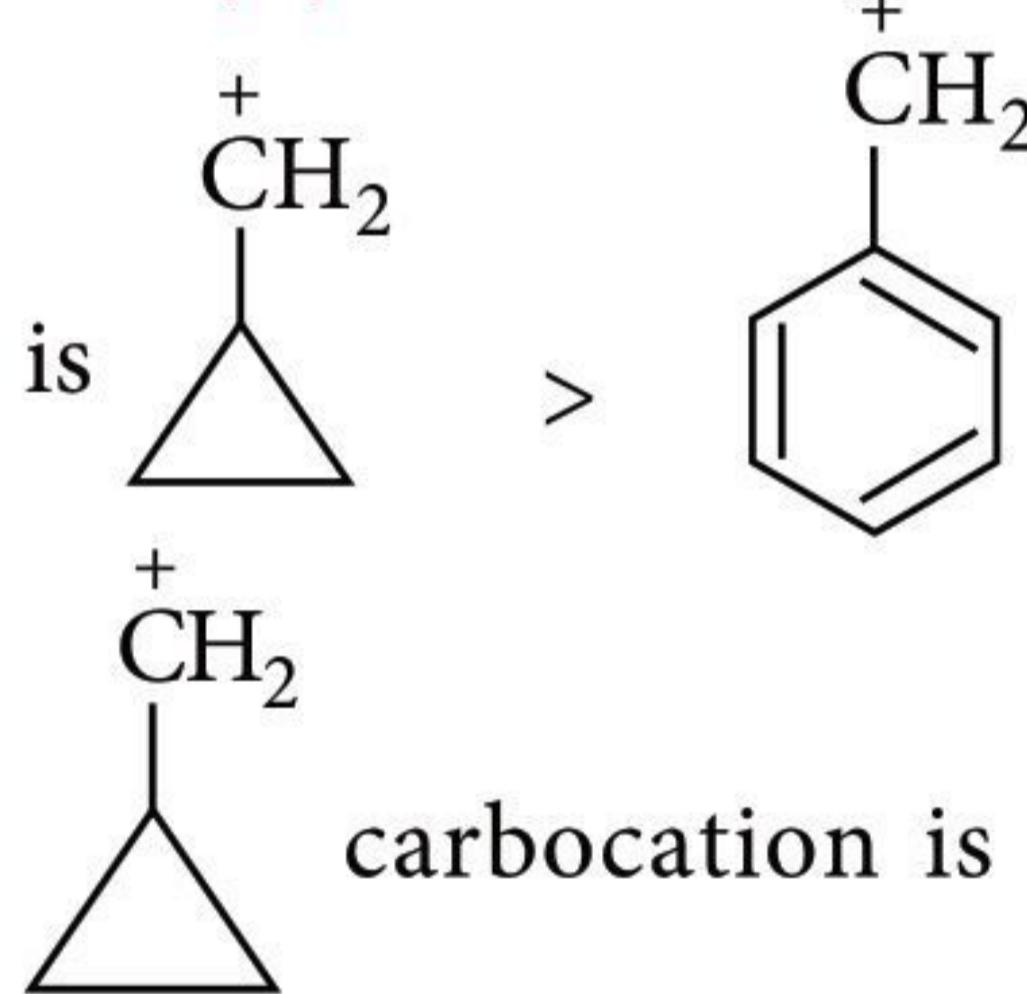


$\text{Trans-}[\text{Co}(\text{Cl}_2(\text{en})_2]^+$  is optically inactive as it has a superimposable mirror image. On the other hand,  $\text{cis-}[\text{CoCl}_2(\text{en})_2]^+$  is optically active and has a non-superimposable mirror image. The IUPAC name of  $\text{K}_2[\text{Cr}(\text{NO})(\text{NH}_3)(\text{CN})_4]$  is potassium Amminetetracyanidonitrosolumchromate(I).

In the given compound  $[\text{CuN}(\text{CH}_3)_4]^+ [\text{BF}_4]^-$ , the oxidation state of Cu is +1, therefore the electronic configuration of  $\text{Cu}^+$  becomes  $[\text{Ar}]3d^{10}$ . As all the  $d$ -orbitals are full-filled so  $d-d$  transition will not be possible, hence colourless,  $[\text{Mn}(\text{CN})_6]^{4-}$  is an inner orbital complex with  $d^2sp^3$  hybridisation and is paramagnetic due to the presence of an unpaired electron.

3. (A)

4. (B) : The correct order of stability of carbocation



carbocation is considered to be more stable

due to the stabilisation through bent orbitals. Hence, compound (B) shows the fastest reaction with HI.

5. (C) : Aniline is more acidic as the negative charge on 'N' atom after releasing  $\text{H}^+$  ion is stabilised through resonance with benzene ring.

6. (C)

7. (B) :  $2\text{C}_6\text{H}_5\text{OH} \rightleftharpoons (\text{C}_6\text{H}_5\text{OH})_2$

At  $t = 0$       1 mole      0  
At eq.       $1 - \alpha$        $\alpha/2$

$$\text{Total} = 1 - \alpha + \frac{\alpha}{2} = 1 - \frac{\alpha}{2}$$

$$i = \frac{1 - (\alpha/2)}{1} = 1 - \frac{\alpha}{2}$$

$$\Delta T_f = i \times K_f \times m$$

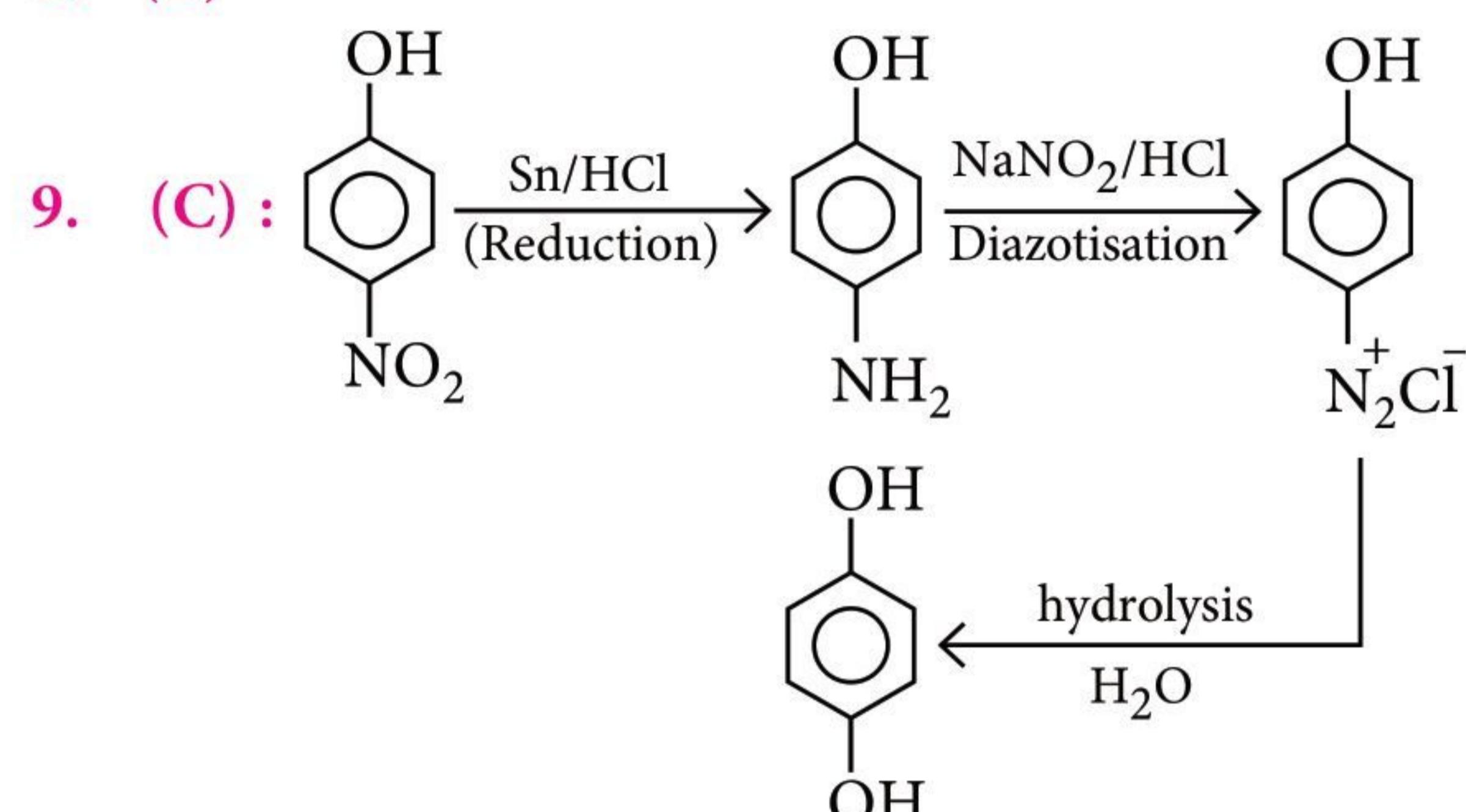
$$0.69 = \left(1 - \frac{\alpha}{2}\right) \times 5.1 \times \frac{20 / \text{M.wt. C}_6\text{H}_5\text{OH}}{1}$$

$$\therefore \text{M.wt. C}_6\text{H}_5\text{OH} = 94 \text{ g mol}^{-1}$$

$$0.69 = \left(1 - \frac{\alpha}{2}\right) \times 1.0851 \Rightarrow \left(1 - \frac{\alpha}{2}\right) = 0.6359$$

$$\Rightarrow \frac{\alpha}{2} = 0.3641 \text{ or } \alpha = 0.7282 \text{ or } 73\%$$

8. (B)



10. (B) : In IV, the presence of the carbonyl group makes the compound more electrophilic and thus, more reactive towards  $\text{S}_{\text{N}}2$  reaction. Compound (I) being less sterically hindered undergoes  $\text{S}_{\text{N}}2$  reaction faster than compound (III). Compound (II) being a secondary alkyl halide undergoes  $\text{S}_{\text{N}}2$  reaction at the slowest rate. Hence, the correct order is :

$$\text{IV} > \text{I} > \text{III} > \text{II}$$

mtG

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CLASS  
**12**

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**11. (A) :** Specific conductance decrease with dilution as the number of ions decreases in consideration with volume. Equivalent conductance increases with increase in dilution due to increase in volume.

**12. (C) :**

$$\text{Effective atomic number} = \frac{\text{Atomic number of metal}}{\text{Number of ligands}} + \left( \frac{\text{Number of ligand} \times \text{Oxidation state of metal}}{\text{number of electrons donated by each ligand}} \right)$$

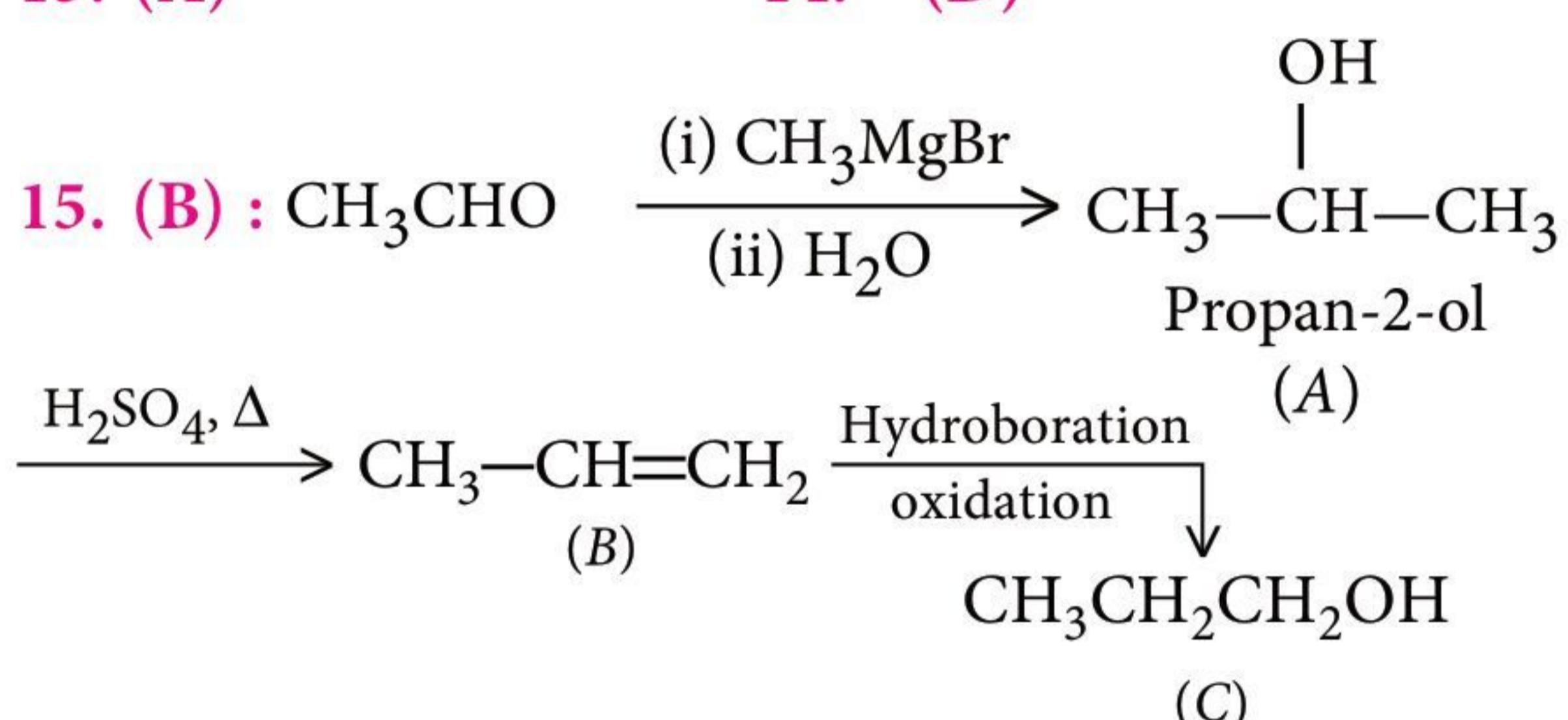
In the given compound, the atomic number of Pt is 78 and oxidation state of Pt = +4.

Number of  $\text{Cl}^-$  ligands is 6 and each  $\text{Cl}^-$  donates two electrons

$$\Rightarrow \text{EAN} = 78 + (2 \times 6) - 4 = 78 + 12 - 4 = 86$$

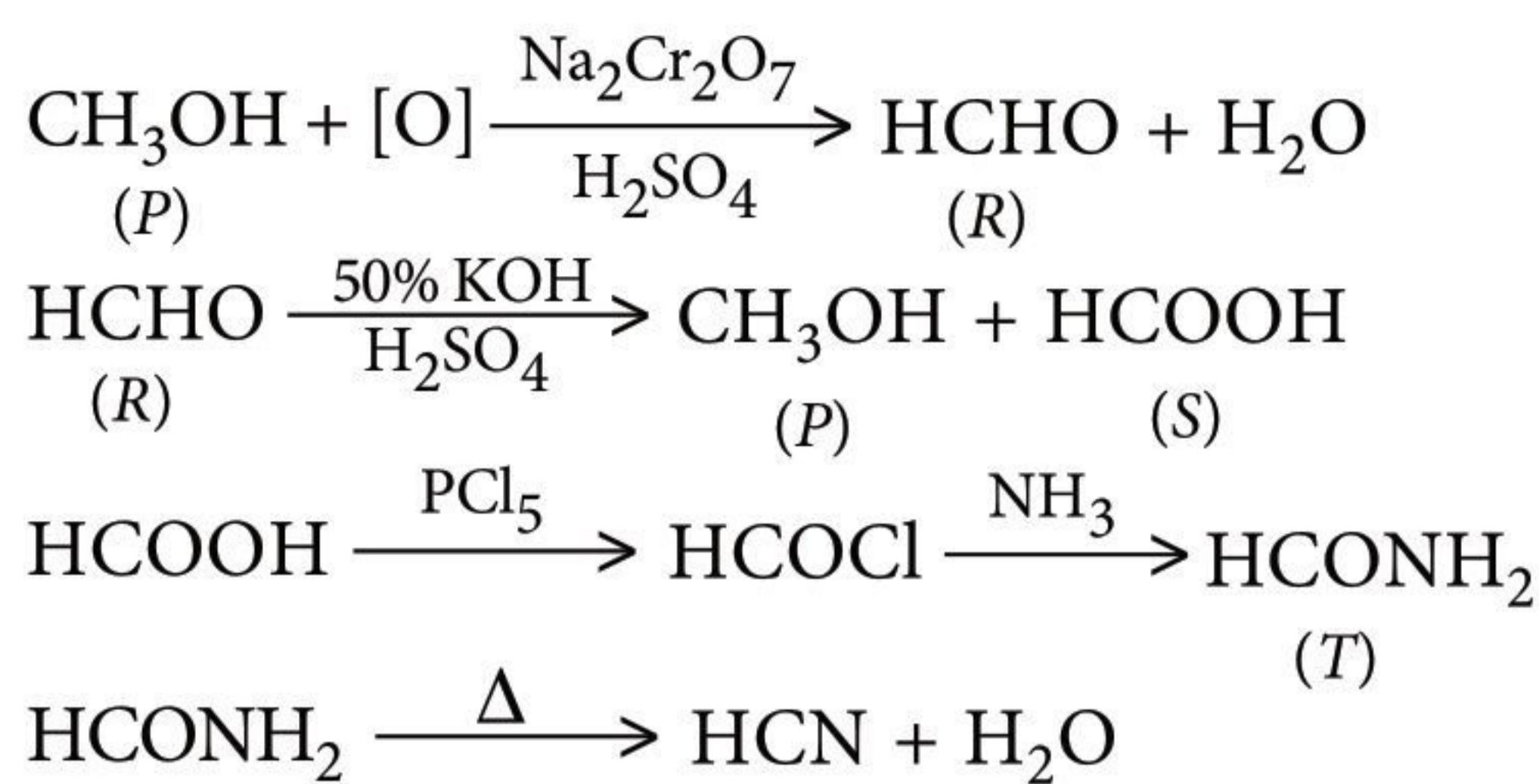
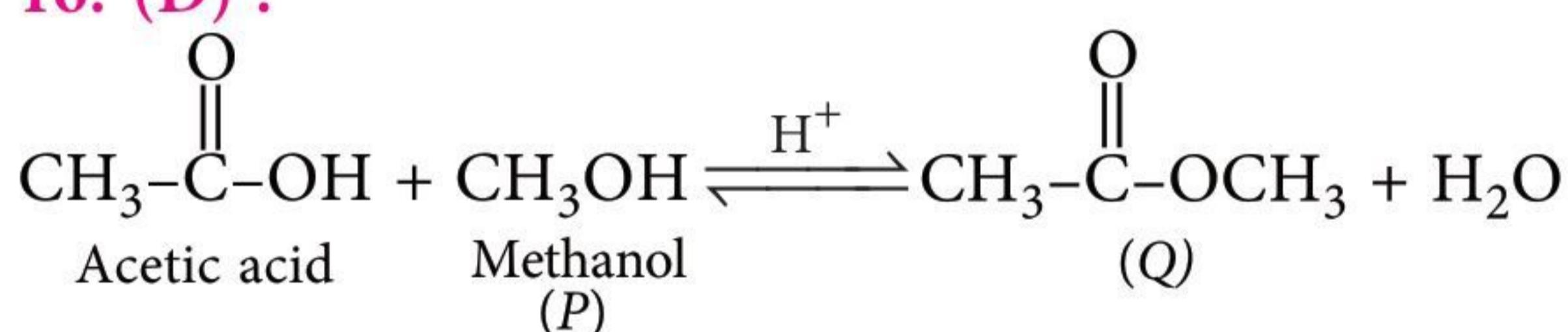
**13. (A)**

**14. (D)**



Compounds (A) and (C) are positional isomers.

**16. (D) :**



**17. (C) :**  $\text{CH}_3\text{Cl}$  being a primary alkyl halide and least sterically hindered undergoes  $\text{S}_{\text{N}}2$  reaction at the highest rate, followed by  $\text{CH}_3\text{CH}_2\text{Cl}$ .  $(\text{CH}_3)_2\text{CHCl}$  undergoes  $\text{S}_{\text{N}}1$  reaction at a slower rate as compared to  $(\text{CH}_3)_3\text{CCl}$  due to the lesser stability of secondary carbocation.  $(\text{CH}_3)_3\text{CCl}$  forms a tertiary carbocation during  $\text{S}_{\text{N}}1$  reaction which is the most stable. Hence it undergoes  $\text{S}_{\text{N}}1$  reaction at the highest rate.

**18. (D)**

**19. (C) :** We know,  $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

$$\Delta G^\circ = -RT \ln K_{\text{eq}}$$

$$-RT \ln K_{\text{eq}} = \Delta H^\circ - T\Delta S^\circ$$

$$\ln K_{\text{eq}} = \frac{\Delta H^\circ}{RT} + \frac{\Delta S^\circ}{R}; y = \frac{-\Delta H^\circ}{R} \frac{1}{T} + \left( \frac{\Delta S^\circ}{R} \right)$$

From the given graph, it is clear that the slope is positive

Hence,  $\frac{\Delta H^\circ}{R} = +\text{ve} \Rightarrow \Delta H^\circ$  will be negative.

Hence, the given reaction is exothermic.

**20. (C)**

For other sections/subjects please refer to  
Physics For You and Biology Today



**Mentor  
Advice**

## 5 Steps to Excel in Olympiads

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- 1 Make an Appropriate Use of Time Tool :** Get to know your syllabus, make a timetable for various subjects, giving more time to the subjects you are weak in.
- 2 Keep Revising at Regular Intervals :** Revise all the topics at regular intervals, as it is imperative for any exam preparation. It helps in remembering the facts, figures, topics and methodologies already covered by you and will surely increase your confidence.
- 3 Practice Previous Years' Papers :** Practice as many previous years' question papers as possible, as it gives a fair idea about the level of difficulty and pattern of questions.
- 4 Study with Good Resource Books :** A good resource book is like a good 'Mentor'. Prepare for Olympiads with right guidance as well as with the best trusted resources.
- 5 Stay Motivated :** Last but not the least, always stay positive and focused. Believe in Yourself!



**CLASS-XI**  
**for**  
**NEET/JEE**

Brush up your concepts to get high rank in NEET/JEE (Main and Advanced) by reading this column. This specially designed column is updated year after year by a panel of highly qualified teaching experts well-tuned to the requirements of these Entrance Tests.

**Unit 2**

## **Classification of Elements and Periodicity in Properties | Chemical Bonding and Molecular Structure**

### **CLASSIFICATION OF ELEMENTS AND PERIODICITY IN PROPERTIES**

#### **GENESIS OF PERIODIC CLASSIFICATION**

- **Dobereiner's triads (1829)** : Dobereiner classified elements into a group of three called triads. In the triads of elements, the atomic weight of the middle element was the arithmetic mean of the atomic weights of the other two *i.e.*, Li(7), Na(23), K(39)  
Mean of atomic masses of 1<sup>st</sup> and 3<sup>rd</sup> element
- $$= \frac{7+39}{2} = 23$$
- **Newlands' law of octaves** : If the elements are arranged in order of their increasing atomic weights, every eighth element had similar properties to the first one, like the first and eighth note of music.
- **Lothar Meyer's atomic volume curve** : Lothar Meyer, plotted a graph between atomic volumes (atomic mass/density) of the elements against their atomic masses and observed that the elements with similar properties occupied similar positions on the curve.
- **Mendeleev's periodic law** : The physical and chemical properties of elements are periodic functions of their atomic weights. If the elements are arranged in the order of their increasing atomic weights, after a regular interval, elements with similar properties are repeated. The table is divided into nine vertical columns called groups and seven horizontal rows called periods.

### **MODERN PERIODIC LAW AND PRESENT FORM OF THE PERIODIC TABLE**

- Moseley suggested that, basis of classification of elements should be the atomic number of the elements rather than the atomic mass of the elements.
- Modern periodic law states that “the physical and chemical properties of the elements are periodic functions of their atomic numbers”. Thus, when the elements were arranged in the order of their increasing atomic numbers, the elements of similar properties appear at regular intervals.
- Long form of periodic table consists of horizontal rows called as '**periods**' and vertical columns called as '**groups**'.
- **Periods** : Modern periodic table has seven horizontal rows known as periods. There is a periodicity occurring at regular intervals of 2, 8, 8, 18, 18, and 32 and so the number 2, 8, 18, and 32 are called **magic numbers**.
- **Groups** : There are 18 groups in the long form of the periodic table and they are numbered from 1 to 18 in the IUPAC system. Generally all the groups are named after first member of each group. There are some common names given to few groups also.
  - Elements of group-1 are called **alkali metals**.
  - Elements of group-2 are called **alkaline earth metals**.
  - Elements of group-11 are called **coinage metals**.
  - Elements of group-15 are called **pniotogens**.
  - Elements of group-16 are called **chalcogens**.
  - Elements of group-17 are called **halogens**.
  - Elements of group-18 are called **noble gases or inactive gases**.

## NOMENCLATURE OF ELEMENTS WITH ATOMIC NUMBERS > 100

- Elements with  $Z > 100$  have been named in IUPAC system.
- Names have been derived from their atomic number using Latin and Greek words for their numbers and adding the suffix-ium.
- Symbol is obtained from first letter of word used for each numerical digit.

## CLASSIFICATION OF ELEMENTS AND GENERAL ELECTRONIC CONFIGURATION

(i) **s-block elements** : The elements in which the last electron enters the s-orbital of their outermost energy level are called **s-block elements** :

General electronic configuration of s-block elements :  $ns^{1-2}$

(ii) **p-block elements** : The elements in which the last electron enters the p-orbital of their outermost energy level are called **p-block elements**.

General electronic configuration of p-block elements :  $ns^2 np^{1-6}$

(iii) **d-block elements** : The elements in which the last electron enters the d-orbitals of their last but one (called penultimate) energy level constitute **d-block elements**.

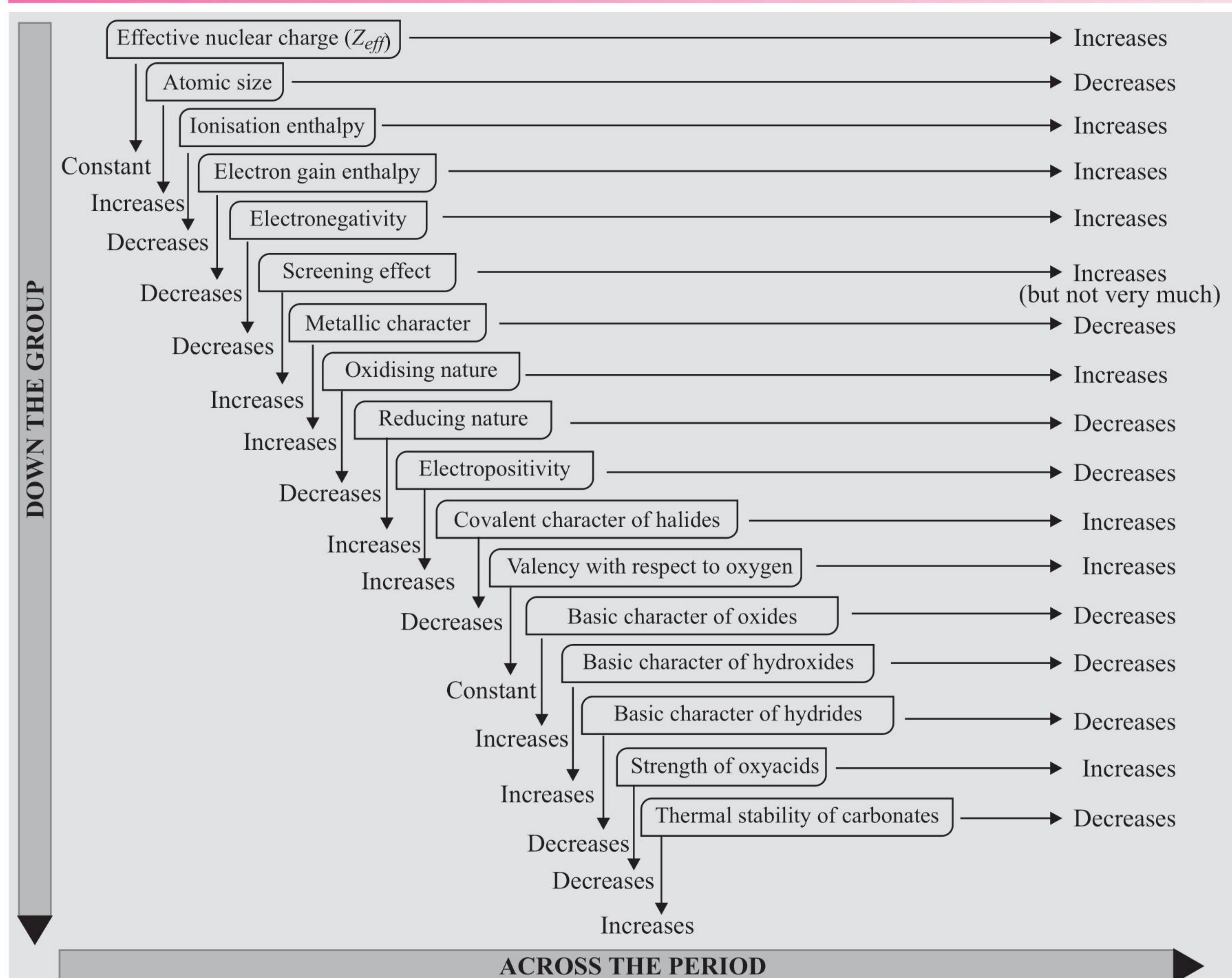
General electronic configuration :  $(n-1) d^{1-10} ns^{0-2}$

(iv) **f-block elements** : The elements in which the last electron enters the f-orbitals of their atoms are called **f-block elements**.

The general electronic configuration :

$(n-2)f^{1-14} (n-1)d^{0-2} ns^2$

## GENERAL TRENDS OF DIFFERENT PERIODIC PROPERTIES IN THE PERIODS AND GROUPS



## CHEMICAL BONDING AND MOLECULAR STRUCTURE

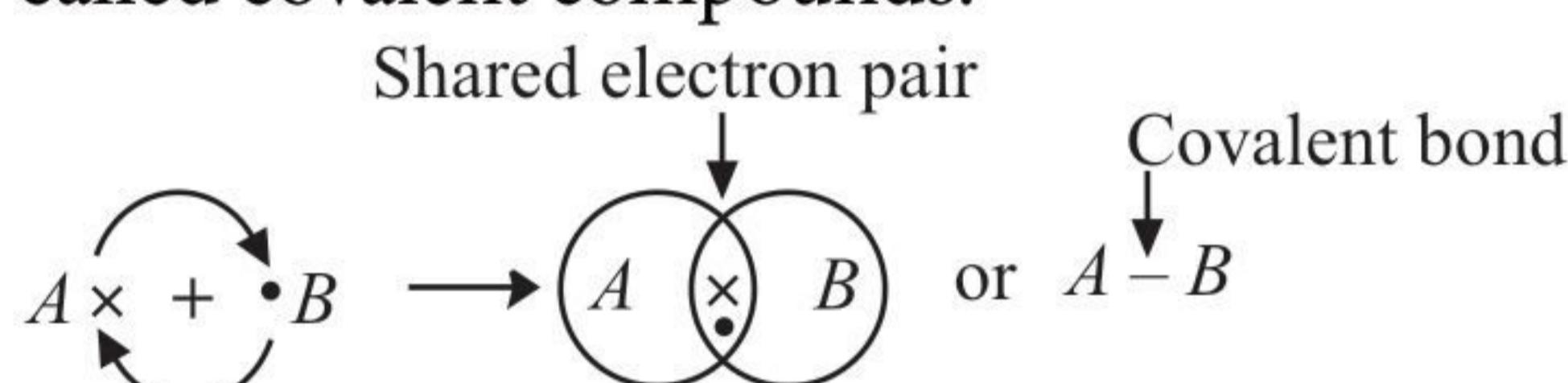
A chemical bond is the attractive force which holds various constituents (atoms, ions, etc.) together in different chemical species.

### KÖSSEL-LEWIS APPROACH TO CHEMICAL BONDING

- Atoms can combine either by transfer of valence electrons from one atom to another (gaining or losing) or by sharing of valence electrons in order to complete their octet or duplet (octet rule).

### COVALENT BOND

- The bond which is formed between two combining atoms by the mutual sharing of electron pair(s) between them is called covalent bond.
- The compounds containing a covalent bond are called covalent compounds.



### LEWIS REPRESENTATION OF SIMPLE MOLECULES

- The Lewis dot structures provide a picture of bonding in molecules and ions in terms of the shared pairs of electrons and the octet rule.
- Lewis representations of a few molecules/ ions are given in following table :

Molecule/ion	Lewis representation
$\text{H}_2$	$\text{H} : \text{H}$
$\text{O}_2$	$\ddot{\text{O}} : \ddot{\text{O}} :$
$\text{O}_3$	$\ddot{\text{O}}^+ : \ddot{\text{O}}^- : \ddot{\text{O}}^-$
$\text{NF}_3$	$\ddot{\text{F}} : \ddot{\text{N}} : \ddot{\text{F}} : \ddot{\text{F}}^-$
$\text{CO}_3^{2-}$	$\left[ \ddot{\text{O}} : \ddot{\text{C}} : \ddot{\text{O}} \right]^{2-}$
$\text{HNO}_3$	$\ddot{\text{O}}^- : \ddot{\text{N}}^+ : \ddot{\text{O}}^- : \text{H}$

Each H-atom attains the configuration of helium (a duplet of electrons).

### FORMAL CHARGE

- To calculate formal charge of an atom in a Lewis structure :

Formal charge = Total no. of electrons in the free atom – Total no. of electrons of lone pairs (non-bonding electrons) –  $1/2 \times$  Total no. of shared electrons (bonding electrons)

### IONIC OR ELECTROVALENT BOND

- An ionic bond is the electrostatic force of attraction between cation and anion formed by complete transfer of electrons from one atom to another so as to attain the stable nearest noble gas configuration.
- A qualitative measure of the stability of an ionic compound is provided by its enthalpy of lattice formation and not simply by achieving octet of electrons around the ionic species in gaseous state.

### LATTICE ENTHALPY

- The lattice enthalpy of an ionic solid is defined as the energy required to completely separate one mole of a solid ionic compound into gaseous constituent ions.
- Factors affecting lattice enthalpy :**
  - Charge on the ions :** Charge on the ions  $\propto$  Force of attraction between ions  $\propto$  Lattice enthalpy  
Accordingly, lattice enthalpies of bi-bivalent ions  $>$  uni-bi or bi-uni  $>$  uni-univalent ions
  - Size of the ions :** Lattice enthalpy  $\propto$  Force of attraction between ions  $\propto \frac{1}{\text{Size of the ions}}$

### COORDINATE BOND

- A covalent bond in which both electrons of the shared pair are contributed by one of the atoms, is called a **coordinate bond** or **dative bond** and the compound is called a **coordinate compound**.
- A covalent bond in which the bond pair is unequally shared such that the atoms acquire a partial positive and negative charge is called a **polar covalent bond**.
- Percentage ionic character  

$$= [16(\chi_A - \chi_B) + 3.5(\chi_A - \chi_B)^2]$$
- Dipole moment,  $\mu = q \times d$   
 Unit of  $\mu$  is Debye (D),  
 $1 \text{ D} = 10^{-18} \text{ esu cm} = 3.33 \times 10^{-30} \text{ C m}$

$$\% \text{ Ionic character} = \frac{\mu_{\text{obs.}}}{\mu_{\text{ionic}}} \times 100$$

# CONCEPT MAP

# SOLID STATE | SOLUTIONS

## SOLID STATE

$$\text{Packing efficiency} = \frac{\text{Volume occupied by each sphere in the unit cell}}{\text{Total volume of the unit cell}} \times 100\%$$

- Mass of unit cell = Number of atoms in a unit cell ( $Z$ )  $\times$  Mass of atom ( $m$ )
- Mass of each atom ( $m$ ) =  $\frac{\text{Molar mass} (M)}{\text{Avogadro's constant} (N_A)}$
- Density ( $\rho$ ) of unit cell of a cubic crystal

$$= \frac{ZM}{V \times N_A} = \frac{ZM}{a^3 \times N_A}$$

Void	Radius Ratio
Triangular	$0.155 \leq r^+ / r^- < 0.225$
Tetrahedral	$0.225 \leq r^+ / r^- < 0.414$
Octahedral	$0.414 \leq r^+ / r^- < 0.732$
Body-centred cubic	$0.732 \leq r^+ / r^- < 1$

## Classification of Solids

**Amorphous Solid** : Constituent particles are not arranged in any regular pattern.

- Short range ordered
- Isotropic
- Supercooled liquids or pseudo solids

**Crystalline Solid** : Constituent particles are arranged in a definite geometric pattern in all the three dimensions.

- Short range as well as long range ordered
- Anisotropic
- True solids
- On the basis of nature of intermolecular forces between them there are four types of crystalline solids :
  - Molecular solids
  - Ionic solids : Non-polar, Polar, Hydrogen bonded
  - Metallic solids
  - Covalent solids

**Polycrystalline Solid** : Some solids, like aluminium and steel, have structure between crystalline and amorphous solids. These polycrystalline solids have large number of small crystals. The small crystals have regular arrangement of constituent units but the crystals themselves are arranged in a random manner.

## Characteristics of Different Types of Unit Cells

Crystal	No. of atom(s)/ unit cell	Packing efficiency	C.No.	Relation in $a$ and $r$
scc	1	52.4%	6	$r = a/2$
bcc	2	68%	8	$r = \frac{\sqrt{3}}{4} a$
fcc	4	74%	12	$r = a/2\sqrt{2}$

## Impurities (Defects) in Solids

- Line Defects** : Irregularities exist in the entire row of lattice points.
- Point Defects** : Irregularities exist around a point or an atom.
- Stoichiometric Defects** :
  - Vacancy Defect
  - Schottky Defect
  - Interstitial Defect
  - Frenkel Defect
- Impurity Defects** : Arises when foreign atoms are present at the lattice site in place of host atoms.
- Non-stoichiometric Defects** :
  - Metal excess defect
  - Metal deficiency defect

## Solids on the Basis of Electrical Properties

- Conductors** : Electrical conductivity,  $10^4$  to  $10^7 \text{ ohm}^{-1} \text{ m}^{-1}$
- Insulators** : Electrical conductivity,  $10^{-20}$  to  $10^{-10} \text{ ohm}^{-1} \text{ m}^{-1}$
- Semiconductors** : Electrical conductivity,  $10^{-6}$  to  $10^4 \text{ ohm}^{-1} \text{ m}^{-1}$ 
  - n-type semiconductors** : Group 14 elements doped with group 15 elements, free electrons increase conductivity.
  - p-type semiconductors** : Group 14 elements doped with group 13 elements, holes increase conductivity.

## SOLUTIONS

### Expressing Concentration of Solution

- Mass percentage** : Mass % of the solution

$$= \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$$

- Parts per million** : ppm of  $A$

$$= \frac{\text{Mass of component } A}{\text{Total mass of solution}} \times 10^6$$

- Molarity** : Molarity ( $M$ ) =  $\frac{\text{Number of moles of solute}}{\text{Volume of solution (L)}}$

- Molality** : Molality ( $m$ ) =  $\frac{\text{Number of moles of solute}}{\text{Mass of solvent in kg}}$

- Mole Fraction** : Mole fraction of a component

$$= \frac{\text{No. of moles of the component}}{\text{Total no. of moles of all the components}}$$

- Normality** : Normality ( $N$ )

$$= \frac{\text{No. of gram equivalent of solute}}{\text{Volume of solution in (mL)}} \times 1000$$

- Henry's law** :  $p_A = K_H x_A$  ;  $K_H$  increases with increase of temperature implying that solubility decreases with increase of temperature at the same pressure.

- Raoult's law** : The law states that "at a given temperature, for a solution of volatile liquids, the partial vapour pressure of each component in solution is equal to the product of the vapour pressure of pure component and its mole fraction".

$$p_A = p_A^0 \times x_A; p_B = p_B^0 \times x_B$$

- Dalton's law of partial pressure** :

$$P_{\text{total}} = p_1 + p_2 + \dots + p_n \text{ and for two components system, } P_{\text{total}} = p_1^0 + (p_2^0 - p_1^0) x_2$$

## Colligative Properties

- Relative lowering in vapour pressure** : The relative lowering in vapour pressure of an ideal solution containing the non-volatile solute is equal to the mole fraction of the solute ( $x_B$ ) at a given temperature.

$$\frac{p_A^0 - p_A}{p_A^0} = x_B$$

- Elevation in boiling point** : Elevation in boiling point (i.e.,  $\Delta T_b$ ) is directly proportional to the molality ( $m$ ) of the solute in solution.

$$\Delta T_b \propto m; \Delta T_b = K_b m$$

where,  $K_b$  = molal elevation constant.

- Depression in freezing point** : Depression in freezing point (i.e.,  $\Delta T_f$ ) is directly proportional to the molal concentration of solute ( $m$ ).

$$\Delta T_f \propto m; \Delta T_f = K_f m$$

where,  $K_f$  = molal depression constant.

- Osmotic Pressure** : At any temperature, the osmotic pressure ( $\pi$ ) of a solution is proportional to the molar concentration ( $C$ ) of the solute and absolute temperature.  $\pi = CRT$ ; where,  $R$  = universal gas constant.

## Ideal and Non-ideal Solutions

Ideal Solutions	Non-ideal Solutions
$p_1 = x_1 p_1^0; p_2 = x_2 p_2^0$	$p_1 \neq x_1 p_1^0; p_2 \neq x_2 p_2^0$
$\Delta H_{\text{mix}} = 0, \Delta V_{\text{mix}} = 0$	$\Delta H_{\text{mix}} \neq 0, \Delta V_{\text{mix}} \neq 0$
$A - B \text{ interactions} \approx A - A \text{ and } B - B \text{ interactions.}$	$A - B \text{ interactions} \neq A - A \text{ and } B - B \text{ interactions.}$

## Non-ideal Solutions Showing Positive and Negative Deviations from Raoult's Law

Solutions showing positive deviation	Solutions showing negative deviation
$A - B \ll A - A \text{ or } B - B \text{ interactions.}$	$A - B \gg A - A \text{ or } B - B \text{ interactions.}$
$\Delta H_{\text{mix}} > 0, \Delta V_{\text{mix}} > 0$	$\Delta H_{\text{mix}} < 0, \Delta V_{\text{mix}} < 0$
$p_1 > p_1^0 x_1$	$p_1 < p_1^0 x_1$

## van't Hoff Factor and its Significance

$$i = \frac{\text{Observed value of colligative property}}{\text{Calculated value of colligative property}}$$

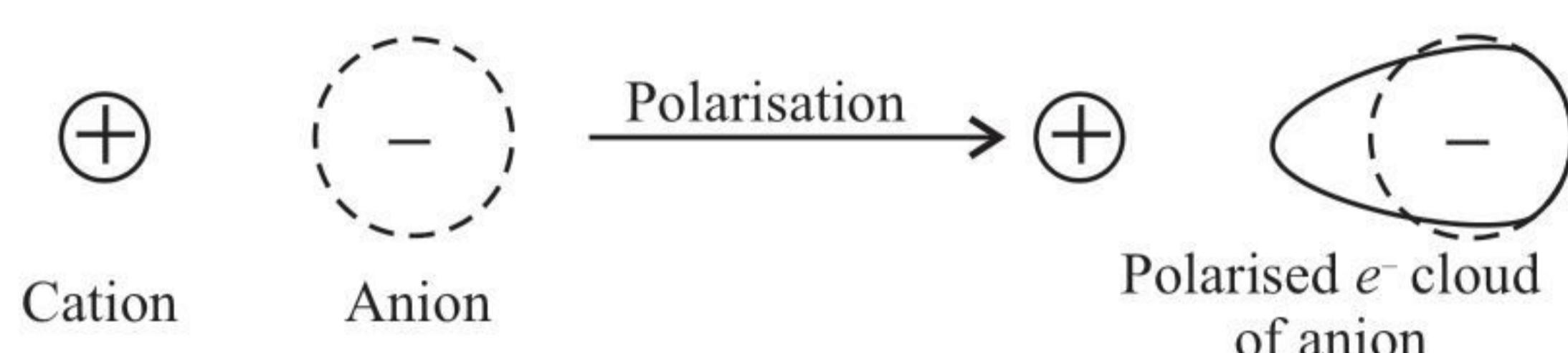
- For association of solute :  $nA \rightarrow (A)_n$   
Degree of association ( $\alpha$ ) =  $(1 - i) n / (n - 1); i < 1$
- For dissociation of solute :  $(A)_n \rightarrow nA$   
Degree of dissociation ( $\alpha$ ) =  $(i - 1) / (n - 1); i > 1$

- Modified colligative properties :

$$p_A^0 - p_A / p_A^0 = i x_B; \Delta T_b = i K_b m; \Delta T_f = i K_f m; \pi = i CRT$$

## FAJAN'S RULE

- According to Fajan's rule, the power of an ion (cation) to distort the electronic cloud of other ion (anion) is known as its polarising or polarisation power, whereas the tendency of an ion (anion) to get polarised by other ion is known as its polarisability. Higher the degree of ionic polarisation greater is the covalent character.



- Polarising power  $\propto \frac{1}{\text{size of cation}}$
- Polarisability of anion  $\propto \text{size of anion}$
- Covalent character  $\propto \text{size of anion} \propto \frac{1}{\text{size of cation}}$   
 $\propto \text{charge on anion and cation.}$

## Some Important Bond Characteristics

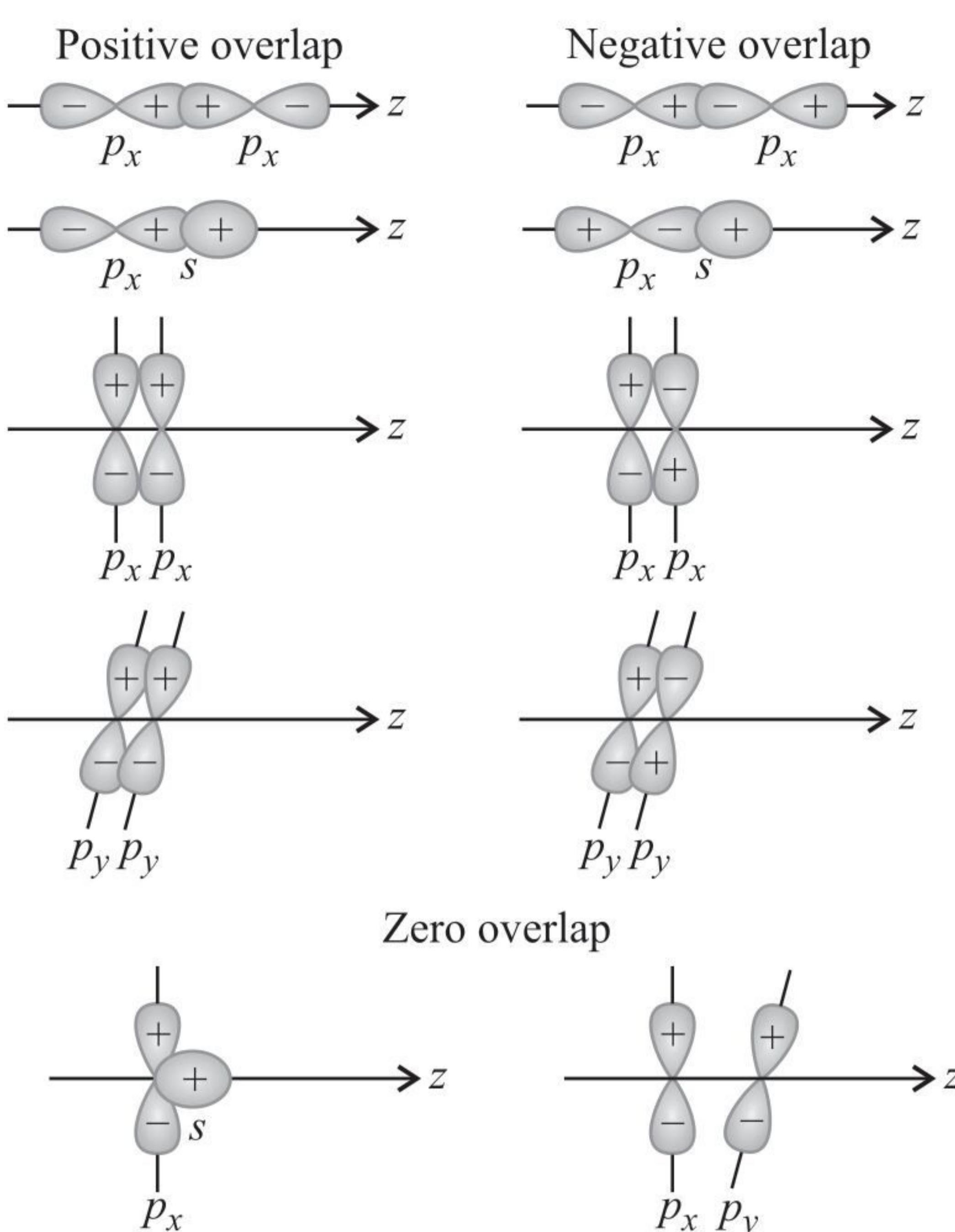
- Bond length  $\propto \text{size of atom} \propto \frac{1}{\% \text{ s-character}}$   
 $\propto \frac{1}{\text{bond multiplicity}}$
- Bond energy  $\propto \frac{1}{\text{bond length}} \propto \% \text{ s-character}$   
 $\propto \frac{1}{\text{no. of lone pairs}}$
- Bond angle  $\propto \% \text{ s-character} \propto \text{electronegativity of central atom} \propto \frac{1}{\text{electronegativity of surrounding atom}}$

## VSEPR THEORY

- According to this theory, bonded atoms in a molecule adopt that arrangement around the central atom which keeps them as far apart as possible. Postulates of the theory are :
  - Shape of a molecule depends upon the number of valence shell electron pairs (bonded or non-bonded) around the central atom.
  - Electron pairs in the valence shell repel one another and the order of repulsion is :  $lp - lp > lp - bp > bp - bp$ .
  - Electron pairs tend to occupy such positions in space that minimise repulsion and maximise distance between them.

## VALENCE BOND THEORY

- Overlapping of atomic orbitals



## HYBRIDISATION

- Pauling introduced the concept of hybridisation. According to him the atomic orbitals combine to form new set of equivalent orbitals known as hybrid orbitals. The phenomenon is known as hybridisation and is defined as the process of intermixing of the orbitals of slightly different energies so as to redistribute their energies, resulting in the formation of new set of orbitals of equivalent energies and shape.
- To predict hybridisation of central atom and shape of molecule/ion :

$$X = \frac{1}{2} \left\{ \begin{array}{l} \text{No. of valence electrons} \\ \text{of the central atom} \end{array} \right\} + \left\{ \begin{array}{l} \text{No. of monovalent atoms/groups} \\ \text{surrounding the central atom} \end{array} \right\} - \left\{ \begin{array}{l} \text{Charge on the cation if the given} \\ \text{species is a polyatomic cation} \end{array} \right\} + \left\{ \begin{array}{l} \text{Charge on the anion if the given} \\ \text{species is a polyatomic anion} \end{array} \right\}$$

$$\text{or } H = \frac{1}{2} [V + M - C + A]$$

## Types of Hybridisation

(a) Two $sp$ hybrids		Linear
(b) Three $sp^2$ hybrids (All orbitals are in the plane of the paper)		All angles = 120° Planar triangular
(c) Four $sp^3$ hybrids		All angles = 109.5° Tetrahedral
(d) Five $sp^3d$ hybrids		Trigonal bipyramidal
(e) Six $sp^3d^2$ hybrids		Octahedral All angles = 90°

- Hybridisation and shapes of some molecules are listed in the given table:

Type of hybridisation	No. of hybrid orbitals	Shape of molecule	Bond angle	Examples
$sp$	2	Linear	180°	$\text{BeCl}_2, \text{BeF}_2, \text{CO}_2, \text{CS}_2, \text{C}_2\text{H}_2, \text{N}_2\text{O}, [\text{Ag}(\text{CN})_2]^-$ , $\text{HgCl}_2, \text{HCN}$
$sp^2$	3	Triangular planar	120°	$\text{BF}_3, \text{BCl}_3, \text{C}_2\text{H}_4, \text{NO}_3^-, \text{CO}_3^{2-}, \text{SO}_3, \text{CH}_3$
$sp^3$	4	Tetrahedral	109.5°	$\text{CH}_4, \text{CCl}_4, \text{SnCl}_4, \text{SiF}_4, \text{NH}_4^+, \text{SO}_4^{2-}$
$dsp^2$	4	Square planar	90°	$[\text{PtCl}_4]^{2-}, [\text{Ni}(\text{CN})_4]^{2-}$
$dsp^3$ or $sp^3d$	5	Trigonal bipyramidal	120° and 90°	$\text{PCl}_5, \text{PF}_5, [\text{Fe}(\text{CO})_5]$
$d^2sp^3$ or $sp^3d^2$	6	Octahedral	90°	$\text{SF}_6, \text{UF}_6, \text{TeF}_6, [\text{CrF}_6]^{3-}, [\text{Co}(\text{NH}_3)_6]^{3+}$
$d^3sp^3$ or $sp^3d^3$	7	Pentagonal bipyramidal	72° and 90°	$\text{IF}_7$

## MOLECULAR ORBITAL THEORY OR LINEAR COMBINATION OF ATOMIC ORBITALS (LCAO)

- Molecular orbitals are formed by the addition or subtraction of wave functions of the atomic orbitals.
- Addition of wave functions during overlap of atomic orbitals leads to formation of bonding orbitals with lower energy levels, they can be  $\sigma$  or  $\pi$ .
- Subtraction of wave functions during overlap of atomic orbitals leads to formation of anti-bonding orbitals with higher energy levels, written as  $\sigma^*$  or  $\pi^*$ .
- Filling of electrons in molecular orbitals takes place in accordance with Aufbau's principle, Hund's rule and Pauli's exclusion principle.
- Energy order for molecular orbitals upto  $\text{N}_2$  is  

$$\sigma 1s < \sigma^* 1s < \sigma 2s < \sigma^* 2s < (\pi 2p_x = \pi 2p_y) < \sigma 2p_z < \pi^* 2p_x = \pi^* 2p_y < \sigma^* 2p_z$$

- Energy order for molecules beyond  $\text{N}_2$   

$$\sigma 1s < \sigma^* 1s < \sigma 2s < \sigma^* 2s < \sigma 2p_z < (\pi 2p_x = \pi 2p_y) < (\pi^* 2p_x = \pi^* 2p_y) < \sigma^* 2p_z$$

### Bond Order

- The number of covalent bonds formed in a molecule is called its bond order. Mathematically, it is defined as half of the difference between the number of bonding and antibonding electrons.
- Bond order (B.O.) =  $\frac{1}{2} (N_b - N_a)$   
Where  $N_b$  is number of electrons present in BMO and  $N_a$  is number of electrons present in ABMO
  - If  $N_b > N_a$ ; B.O. = +ve, the molecule is stable.
  - If  $N_b < N_a$ ; B.O. = -ve, the molecule is unstable or does not exist.
  - If  $N_b = N_a$ ; B.O. = 0, the molecule is unstable or does not exist.
- Isoelectronic species have same bond order.



# WRAP it up!

## MCQs TYPE QUESTIONS

- Which one is an electron deficient compound?  
(a)  $\text{NH}_3$  (b)  $\text{ICl}$  (c)  $\text{BCl}_3$  (d)  $\text{PCl}_3$
- The ground state valence shell electronic configuration of nitrogen molecule ( $\text{N}_2$ ) is written as  $\text{KK}, \sigma 2s^2, \sigma^* 2s^2, \pi 2p_x^2 = \pi 2p_y^2, \sigma 2p_z^2$ . Hence the bond order in  $\text{N}_2$  is  
(a) 2 (b) 3 (c) 0 (d) 1
- The increasing order of bond order of  $\text{O}_2$ ,  $\text{O}_2^+$ ,  $\text{O}_2^-$  and  $\text{O}_2^{2-}$  is  
(a)  $\text{O}_2^+ < \text{O}_2 < \text{O}_2^- < \text{O}_2^{2-}$  (b)  $\text{O}_2^{2-} < \text{O}_2^- < \text{O}_2^+ < \text{O}_2$   
(c)  $\text{O}_2 < \text{O}_2^+ < \text{O}_2^- < \text{O}_2^{2-}$  (d)  $\text{O}_2^{2-} < \text{O}_2^- < \text{O}_2 < \text{O}_2^+$
- In compound X, all the bond angles are exactly  $109^\circ 28'$ . X is  
(a) chloromethane (b) carbon tetrachloride  
(c) iodoform (d) chloroform.
- The first ionization potentials (eV) of Be and B respectively are  
(a) 8.29, 8.29 (b) 9.32, 9.32  
(c) 8.29, 9.32 (d) 9.32, 8.29
- The central atom does not assume  $sp^2$  hybridisation in  
(a)  $\text{PCl}_3$  (b)  $\text{SO}_3$  (c)  $\text{BF}_3$  (d)  $\text{NO}_3^-$
- Match List-I with List-II.

List I (Compound)		List II (Shape)	
(A)	$\text{BrF}_5$	(I)	bent
(B)	$[\text{CrF}_6]^{3-}$	(II)	square pyramidal
(C)	$\text{O}_3$	(III)	trigonal bipyramidal
(D)	$\text{PCl}_5$	(IV)	octahedral

Choose the correct answer from the options given below:

- (A)-(I), (B)-(II), (C)-(III), (D)-(IV)
- (A)-(IV), (B)-(III), (C)-(II), (D)-(I)
- (A)-(II), (B)-(IV), (C)-(I), (D)-(III)
- (A)-(III), (B)-(IV), (C)-(II), (D)-(I)

- Which one of the following is the correct order of the strength of bonding interactions?  
(a) Covalent < hydrogen bonding < van der Waals' < dipole-dipole  
(b) van der Waals' < hydrogen bonding < dipole-dipole < covalent  
(c) van der Waals' < dipole-dipole < hydrogen bonding < covalent  
(d) Dipole-dipole < van der Waals' < hydrogen bonding < covalent.
- CO is practically non-polar since  
(a) the  $\sigma$ -electron drift from C to O is almost nullified by the  $\pi$ -electron drift from O to C  
(b) the  $\sigma$ -electron drift from O to C is almost nullified by the  $\pi$ -electron drift from C to O  
(c) the bond moment is low  
(d) there is a triple bond between C and O.
- The percentage of s-character in the hybrid orbitals  $sp$ ,  $sp^2$  and  $sp^3$  follows the order  
(a)  $sp^3 > sp^2 > sp$  (b)  $sp > sp^2 > sp^3$   
(c)  $sp = sp^2 > sp^3$  (d)  $sp = sp^2 = sp^3$
- Amongst the following, the incorrect statement is  
(a) NO has one unpaired electron in the antibonding molecular orbital  
(b)  $\text{NO}^+$  is more stable than  $\text{O}_2^+$   
(c)  $\text{OF}^+$  is more paramagnetic than  $\text{Ne}_2^+$   
(d) In a  $\pi$ -bond, the electron density is concentrated along the bond axis.
- Which one of the following has T-shaped structure?  
(a)  $\text{ClF}_3$  (b)  $\text{IF}_5$  (c)  $\text{BF}_3$  (d)  $[\text{NH}_4]^+$
- Which of the following hydrogen halides has the highest percentage of ionic character?  
(a) HF (b) HBr (c) HCl (d) HI
- The correct order of the bond angles is  
(a)  $\text{NH}_3 > \text{H}_2\text{O} > \text{PH}_3 > \text{H}_2\text{S}$   
(b)  $\text{NH}_3 > \text{PH}_3 > \text{H}_2\text{O} > \text{H}_2\text{S}$   
(c)  $\text{NH}_3 > \text{H}_2\text{S} > \text{PH}_3 > \text{H}_2\text{O}$   
(d)  $\text{PH}_3 > \text{H}_2\text{S} > \text{NH}_3 > \text{H}_2\text{O}$ .
- One of the characteristic properties of non-metals is that they  
(a) are reducing agents

(b) form basic oxides  
 (c) form cations by electron gain  
 (d) are electronegative.

16. In which of the following pairs both the species have  $sp^3$  hybridization?  
 (a)  $SiF_4$ ,  $BeH_2$       (b)  $NF_3$ ,  $H_2O$   
 (c)  $NF_3$ ,  $BF_3$       (d)  $H_2S$ ,  $BF_3$

17. The shape of  $XeOF_2$  on the basis of VSEPR theory is  
 (a) see-saw      (b) V-shaped  
 (c) trigonal planar      (d) T-shaped.

18. Elements of which of the following groups will form anions most readily?  
 (a) Oxygen family      (b) Nitrogen family  
 (c) Halogens      (d) Alkali metals

19. The electropositive character decreases from  
 (a) Li to Cs (lithium to caesium) in the I group  
 (b) Cl to I (chlorine to iodine) in the VII group  
 (c) Al to Na (aluminium to sodium) in the same period  
 (d) none of the above.

20. Ionic radii are  
 (a) inversely proportional to effective nuclear charge  
 (b) inversely proportional to square of effective nuclear charge  
 (c) directly proportional to effective nuclear charge  
 (d) directly proportional to square of effective nuclear charge.

#### NUMERICAL VALUE TYPE QUESTIONS

21. Among the following, the number of elements showing only one non-zero oxidation state is O, Cl, F, N, P, Sn, Tl, Na, Ti

22.  $AB_3$  is an interhalogen T-shaped molecule. The number of lone pairs of electrons on A is \_\_\_\_.

23. The difference between bond orders of  $CO$  and  $NO^+$  is  $x/2$  where  $x =$  \_\_\_\_\_. (Round off to the nearest integer)

24.  $AX$  is a covalent diatomic molecule where  $A$  and  $X$  are second row elements of periodic table. Based on molecular orbital theory, the bond order of  $AX$  is 2.5. The total number of electrons in  $AX$  is \_\_\_\_\_. (Round off to the Nearest Integer).

25. Number of amphoteric compounds among the following is \_\_\_\_\_.  
 $BeO$ ,  $BaO$ ,  $Be(OH)_2$ ,  $Sr(OH)_2$ .

#### SOLUTIONS

1. (c)

2. (b): Number of electrons in bonding orbitals,  $N_b = 10$  and number of electrons in antibonding orbitals,  $N_a = 4$ .  
 Therefore bond order =  $1/2(N_b - N_a) = 1/2(10 - 4) = 3$

3. (d): In  $O_2^{2-}$  and  $O_2^-$ , the added extra electron enters the antibonding orbital which decreases the bond order. In  $O_2^+$ , the electron is removed from antibonding orbital which increases the bond order.

4. (b): All C – Cl bonds are directed towards the corner of a regular tetrahedron.

5. (d):  ${}^4Be \rightarrow 1s^2 2s^2$ ,  ${}^5B \rightarrow 1s^2 2s^2 2p^1$   
 Due to stable fully-filled 's'-orbital arrangement of electrons in 'Be' atom, more energy is required to remove an electron from the valence shell than 'B'-atom. Therefore 'Be' has higher ionisation potential than 'B'.

6. (a): In  $BF_3$ ,  $NO_3^-$  and  $SO_3$ , the central atom assumes  $sp^2$  hybridisation whereas in  $PCl_3$ , P-atom assumes  $sp^3$  hybridisation.

7. (c)      8. (c)      9. (a)

10. (b): Percentage of s-character decreases as  $sp$  (50%)  $> sp^2$  (33.3%)  $> sp^3$  (25%).

mtg

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11. (d): In a  $\pi$ -bond, the electron density is concentrated in the region perpendicular to the bond axis.

12. (a)

13. (a): The electronegativity difference in HF (4 - 2.1 = 1.9) is highest and so HF has highest percentage of ionic character.

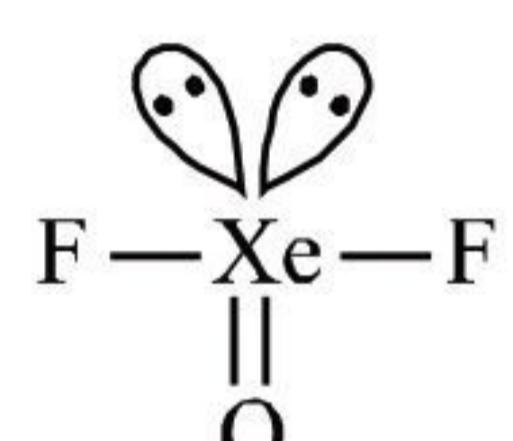
14. (a):  $\text{NH}_3 > \text{H}_2\text{O} > \text{PH}_3 > \text{H}_2\text{S}$   
107.5° 104.5° 93.4° 92.5°

15. (d)

16. (b)

17. (d):  $\text{XeOF}_2$ :

Geometry  $\rightarrow$  Trigonal Bipyramidal  
Shape  $\rightarrow$  T-shape  
Hybridisation  $\rightarrow sp^3d$



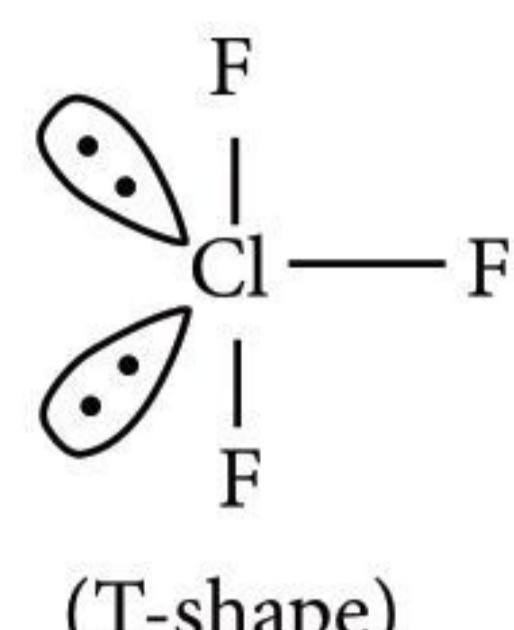
18. (c): As halogens have seven electrons ( $ns^2np^5$ ) in the valence shell, they have a strong tendency to acquire the nearest inert gas configuration by gaining an electron and form halide ions.

19. (d): Electropositive character decreases from left to right in a period. In a group, electropositive character increases as we move down the group.

20. (a)

21. (2): Na exhibits only +1 and F exhibits only -1 oxidation state. Rest of the elements show more than one non-zero oxidation state.

22. (2):  $AB_3$  is T-shaped hence, it may be  $\text{ClF}_3$ .



(T-shape)

23. (0): Bond order of CO = 3

Bond order of  $\text{NO}^+$  = 3; So,  $x = 0$

24. (15): NO is a covalent diatomic molecule having bond order of 2.5.

Total no. of electrons in NO = 7 + 8 = 15

25. (2):  $\text{BeO}$  — Amphoteric oxide

$\text{BaO}$  — Basic oxide

$\text{Be}(\text{OH})_2$  — Amphoteric hydroxide

$\text{Sr}(\text{OH})_2$  — Basic hydroxide



## Delhi zone leads JEE(Advanced) with 133 in top 500, Madras has 132

### Tough Test, Covid Disruptions Push Cutoff To New Low

A general category candidate with 55 marks out of 360 is eligible for a seat in the IITs this year—which makes it the lowest cutoff ever; last year's cutoff was 63. The minimum percentage to the aggregate score also fell to 15.3 as compared to 17.5 in 2020.

A tough JEE (Advanced) test and difficult years of preparation during the pandemic probably led to this new low in the entrance results for the 23 Indian Institutes of Technology (IITs) announced on Sunday morning by IIT-Bombay, the organising institute.

But the good news is that girls from the current batch outperformed those from last year with seven making it to the top

94% OF TOP 500 & 100% OF TOP 15 ARE BOYS

HOW THE ZONES PERFORMED		
Zone	Top 10	Top 500
Madras	5 (3*)	132 (135)
Bombay	3 (2)	126 (137)
Delhi	1 (4)	133 (108)
Kharagpur	1 (0)	31 (38)
Roorkee	0 (1)	45 (49)
Kanpur	0 (0)	23 (24)
Guwahati	0 (0)	10 (9)

(\*2020 figures in bracket)

22 FROM DELHI  
ZONE IN TOP 100



**Shishir RK**  
ALL-INDIA TOPPER  
Narayana  
e-techno school,  
Bengaluru;  
IIT Bombay zone  
Marks : 314/360



**Tanishka Kabra**  
ALL-INDIA GIRL TOPPER  
(AIR 16)  
St Ann's  
Ahmedabad;  
IIT Delhi zone  
Marks : 277/360

34,196 Boys & 6,516  
girls (16% of total 40,712  
candidates) qualify

Top 100 has 93  
boys & 7 girls; top  
500 has 469 boys

Mayank Motwani is the Delhi zone topper (AIR 5) & Dwarka's Harsh Kumar (AIR 21) Delhi state topper. The zone has 22 candidates in top 100

100 as compared to just one last year. The IIT-Delhi zone had the most number of students (133) in the top 500 of the JEE (Advanced) 2022 results. IIT-Madras circle, which is home to the highest number of top 10 rankers (five), closely followed at 132. IIT-Bombay

zone, with three rankers among the top 10, had the third highest count of top 500 rankers.

Like several years now, not a single Mumbai student made it to the top 10 ranks.

Courtesy : The Times of India



# CBSE warm-up!

CLASS-XI

Chapterwise practice questions for CBSE Exams as per the latest pattern  
and reduced syllabus by CBSE for the academic session 2022-23.

Series-3

## Thermodynamics

Time Allowed : 3 hours  
Maximum Marks : 70

### General Instructions

*Read the following instructions carefully.*

- (a) There are 35 questions in this question paper with internal choice.
- (b) SECTION A consists of 18 multiple-choice questions carrying 1 mark each.
- (c) SECTION B consists of 7 very short answer questions carrying 2 marks each.
- (d) SECTION C consists of 5 short answer questions carrying 3 marks each.
- (e) SECTION D consists of 2 case-based questions carrying 4 marks each.
- (f) SECTION E consists of 3 long answer questions carrying 5 marks each.
- (g) All questions are compulsory.
- (h) Use of log tables and calculators is not allowed

### SECTION A

**The following questions are multiple-choice questions with one correct answer. Each question carries 1 mark. There is no internal choice in this section.**

1. The enthalpy change when 2.63 g of phosphorus reacts with an excess of bromine according to the equation :  
[Given: Molar mass of phosphorus = 30.97 g mol<sup>-1</sup>]  
 $2P_{(s)} + 3Br_{2(l)} \longrightarrow 2PBr_{3(g)}$ ;  $\Delta_rH^\circ = -243 \text{ kJ mol}^{-1}$  will be  
(a) 103 kJ (b) 10.3 kJ (c) 20.6 kJ (d) 24.3 kJ
2. The heats of combustion of carbon and carbon monoxide are -393.5 and -283.5 kJ mol<sup>-1</sup> respectively. The heat of formation (in kJ mol<sup>-1</sup>) of carbon monoxide per mole is  
(a) 110 (b) 676.7 (c) -677.5 (d) -110
3. Which among the following equations represents the first law of thermodynamics under isobaric conditions?  
(a)  $\Delta U = q_p - p_{ex}\Delta V$  (b)  $q_v = \Delta U$   
(c)  $\Delta U = w$  (d)  $w = -q$

4. Among the following pairs, which one has both variables as intensive variable?  
(a)  $T, V$  (b)  $m, P$  (c)  $d, V$  (d)  $P, T$
5. The molar heat capacity of water at constant pressure,  $P$  is  $75 \text{ J K}^{-1} \text{ mol}^{-1}$ . When 10 kJ of heat is supplied to 1 kg water which is free to expand, the increase in temperature of water is  
(a) 2.4 K (b) 4.8 K (c) 3.2 K (d) 10 K
6. Which of the following conditions regarding the chemical process ensures its spontaneity at all temperatures ?  
(a)  $\Delta H < 0$  and  $\Delta S < 0$  (b)  $\Delta H > 0$  and  $\Delta S < 0$   
(c)  $\Delta H < 0$  and  $\Delta S > 0$  (d)  $\Delta H > 0$  and  $\Delta S > 0$
7. Calculate the work done by 16 g of oxygen gas (assume ideal behaviour) of molar mass 32 g mol<sup>-1</sup> undergoing isothermal reversible expansion at 300 K from an initial volume of 2.5 L to the final volume of 25 L in litre atm.  
( $R = 8.2 \times 10^{-2} \text{ L atm K}^{-1} \text{ mol}^{-1}$ )  
(a) -56.64 (b) 28.32 (c) 113.28 (d) 56.64

8. For the reaction,  $2\text{Cl}_{(g)} \rightarrow \text{Cl}_{2(g)}$ , the correct option is  
 (a)  $\Delta_rH > 0$  and  $\Delta_rS > 0$  (b)  $\Delta_rH > 0$  and  $\Delta_rS < 0$   
 (c)  $\Delta_rH < 0$  and  $\Delta_rS > 0$  (d)  $\Delta_rH < 0$  and  $\Delta_rS < 0$

9. The values of heat of formation of  $\text{SO}_2$  and  $\text{SO}_3$  are  $-298.2 \text{ kJ}$  and  $-98.2 \text{ kJ}$ . The heat of formation of the reaction,  $\text{SO}_2 + \frac{1}{2}\text{O}_2 \rightarrow \text{SO}_3$  will be  
 (a)  $+200 \text{ kJ}$  (b)  $+396.4 \text{ kJ}$   
 (c)  $-200 \text{ kJ}$  (d)  $-396.4 \text{ kJ}$

10. Enthalpy change for the process,  
 $\text{H}_2\text{O}(\text{ice}) \rightleftharpoons \text{H}_2\text{O}(\text{water})$   
 is  $6.01 \text{ kJ mol}^{-1}$ . The entropy change of 1 mole of ice at its melting point will be  
 (a)  $12 \text{ J K}^{-1} \text{ mol}^{-1}$  (b)  $22 \text{ J K}^{-1} \text{ mol}^{-1}$   
 (c)  $100 \text{ J K}^{-1} \text{ mol}^{-1}$  (d)  $30 \text{ J K}^{-1} \text{ mol}^{-1}$ .

11. A reaction is at equilibrium at  $100^\circ\text{C}$  and the enthalpy change for the reaction is  $42.6 \text{ kJ mol}^{-1}$ . What will be the value of  $\Delta S$  in  $\text{J K}^{-1} \text{ mol}^{-1}$ ?  
 (a)  $120$  (b)  $426.2$  (c)  $373.1$  (d)  $114.2$

12. The equilibrium constant for a reaction is 10. What will be the value of  $\Delta G^\circ$  at  $300 \text{ K}$ ?  
 (a)  $-5.74 \text{ kJ}$  (b)  $-574 \text{ kJ}$  (c)  $57.4 \text{ kJ}$  (d)  $5.74 \text{ kJ}$

13. The enthalpy of formation of water is  
 [Given that the bond energies of  $\text{H}-\text{H}$ ,  $\text{O}=\text{O}$  and  $\text{O}-\text{H}$  bonds are  $433 \text{ kJ/mol}$ ,  $492 \text{ kJ/mol}$  and  $464 \text{ kJ/mol}$ , respectively]  
 (a)  $430 \text{ kJ/mol}$  (b)  $-249 \text{ kJ/mol}$   
 (c)  $-461 \text{ kJ/mol}$  (d)  $215 \text{ kJ/mol}$

14.  $C_p - C_v = R$ . This  $R$  is  
 (a) change in kinetic energy  
 (b) change in rotational energy  
 (c) change in vibrational energy  
 (d) work done which system can do on expanding the gas per mol per degree increase in temperature.

15. Given below are two statements labelled as Assertion (A) and Reason (R)  
**Assertion :** Heat given to a system under constant volume is used up in increasing energy instead of work done.  
**Reason :** Mechanical work done is zero at constant volume.  
 (a) Both A and R are true and R is the correct explanation of A.  
 (b) Both A and R are true but R is not the correct explanation of A.  
 (c) A is true but R is false.  
 (d) A is false but R is true.

16. Given below are two statements labelled as Assertion (A) and Reason (R)

**Assertion :** A reaction which is spontaneous and accompanied by decrease of randomness must be exothermic.

**Reason :** All exothermic reactions are accompanied by decrease of randomness.

(a) Both A and R are true and R is the correct explanation of A.  
 (b) Both A and R are true but R is not the correct explanation of A.  
 (c) A is true but R is false.  
 (d) A is false but R is true.

17. Given below are two statements labelled as Assertion (A) and Reason (R)

**Assertion :** The thermodynamic function which determines the spontaneity of a process is the free energy. For a process to be spontaneous, the change in free energy must be negative.

**Reason :** The change in free energy is related to the change in enthalpy and change in entropy. The change in entropy for a process must always be positive if it is spontaneous.

(a) Both A and R are true and R is the correct explanation of A.  
 (b) Both A and R are true but R is not the correct explanation of A.  
 (c) A is true but R is false.  
 (d) A is false but R is true.

18. Given below are two statements labelled as Assertion (A) and Reason (R)

**Assertion :** There is no exchange in internal energy in a cyclic process.

**Reason :** Cyclic process is the one in which the system returns to its state after a number of reactions.

(a) Both A and R are true and R is the correct explanation of A.  
 (b) Both A and R are true but R is not the correct explanation of A.  
 (c) A is true but R is false.  
 (d) A is false but R is true.

## SECTION B

This section contains 7 questions with internal choice in two questions. The following questions are very short answer type and carry 2 marks each.

19. Comment on the spontaneity of a reaction at constant temperature and pressure in the following cases :

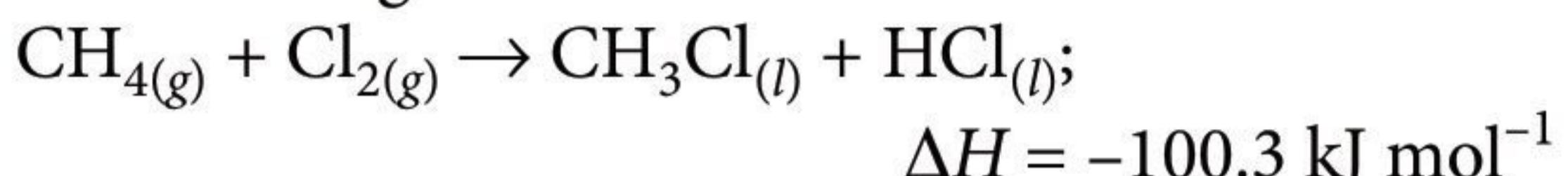
(i)  $\Delta H < 0$  and  $\Delta S > 0$  (ii)  $\Delta H > 0$  and  $\Delta S > 0$

20. Justify the following statements :

(a) Many thermodynamically feasible reactions do not occur under ordinary conditions.

(b) At low temperature, enthalpy change dominates the value of  $\Delta G$  and at high temperature, it is the entropy which dominates the value of  $\Delta G$ .

21. Calculate the bond enthalpy of Cl—Cl bond from the following data :



Given, bond enthalpies of C—H, C—Cl and H—Cl bonds are 413, 326 and 431  $\text{kJ mol}^{-1}$  respectively.

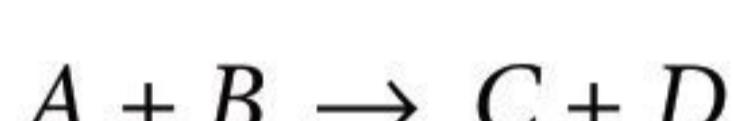
22. 10 g of argon gas is compressed isothermally and reversibly at a temperature of 27°C from 10 litre to 5 litre. Calculate  $q$ ,  $w$  and  $\Delta U$  for this process.  
( $R = 2.0 \text{ cal K}^{-1} \text{ mol}^{-1}$ , Atomic weight of Argon = 40  $\text{g mol}^{-1}$ )

**OR**

The molar heat of formation of  $\text{NH}_4\text{NO}_{3(s)}$  is  $-367.54 \text{ kJ}$  and those of  $\text{N}_2\text{O}_{(g)}$  and  $\text{H}_2\text{O}_{(l)}$  are  $+81.46 \text{ kJ}$  and  $-285.78 \text{ kJ}$  respectively at 25°C and 1.0 atmospheric pressure. Calculate  $\Delta H$  and  $\Delta U$  for the reaction,  $\text{NH}_4\text{NO}_{3(s)} \rightarrow \text{N}_2\text{O}_{(g)} + 2\text{H}_2\text{O}_{(l)}$

23. The enthalpy of reaction for the reaction :  
 $2\text{H}_{2(g)} + \text{O}_{2(g)} \rightarrow 2\text{H}_2\text{O}_{(l)}$  is  $\Delta_r H^\circ = -572 \text{ kJ mol}^{-1}$ . What will be standard enthalpy of formation of  $\text{H}_2\text{O}_{(l)}$ ?

**OR**



$$\Delta H = -10000 \text{ J mol}^{-1}; \Delta S = -33.3 \text{ J K}^{-1} \text{ mol}^{-1}$$

(i) At what temperature the reaction will occur spontaneously from left to right?  
(ii) At what temperature, the reaction will reverse?

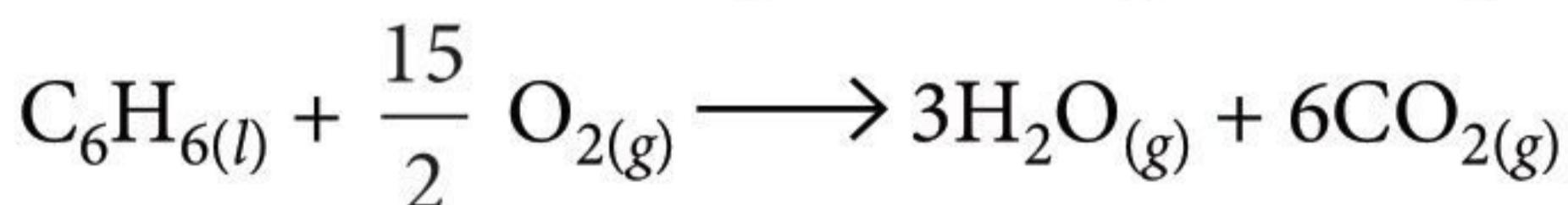
24. (a) What is a thermochemical equation?  
(b) Write one application of Hess's law.

25. If the combustion of 1 g of graphite produces 20.7 kJ of heat, what will be molar enthalpy change? Give the significance of sign also.

### SECTION C

This section contains 5 questions with internal choice in two questions. The following questions are short answer type and carry 3 marks each.

26. Benzene burns in  $\text{O}_2$  according to the equation:



If enthalpy of formation of  $\text{C}_6\text{H}_{6(l)}$ ,  $\text{H}_2\text{O}_{(g)}$  and  $\text{CO}_{2(g)}$  are 11.7,  $-68.3$ , and  $-94$  kcal respectively, calculate the amount of heat liberated by burning 1 kg benzene.

27. What do you mean by the law of conservation of energy? Derive a mathematical relationship between heat, internal energy, and work done by the system.

28. 20.0 g of ammonium nitrate ( $\text{NH}_4\text{NO}_3$ ) is dissolved in 125 g of water in a coffee-cup calorimeter. The temperature falls from 296.5 K to 286.4 K. Find the value of  $q$  for the calorimeter. (Consider heat capacity of water as the heat capacity of the calorimeter and its contents.)

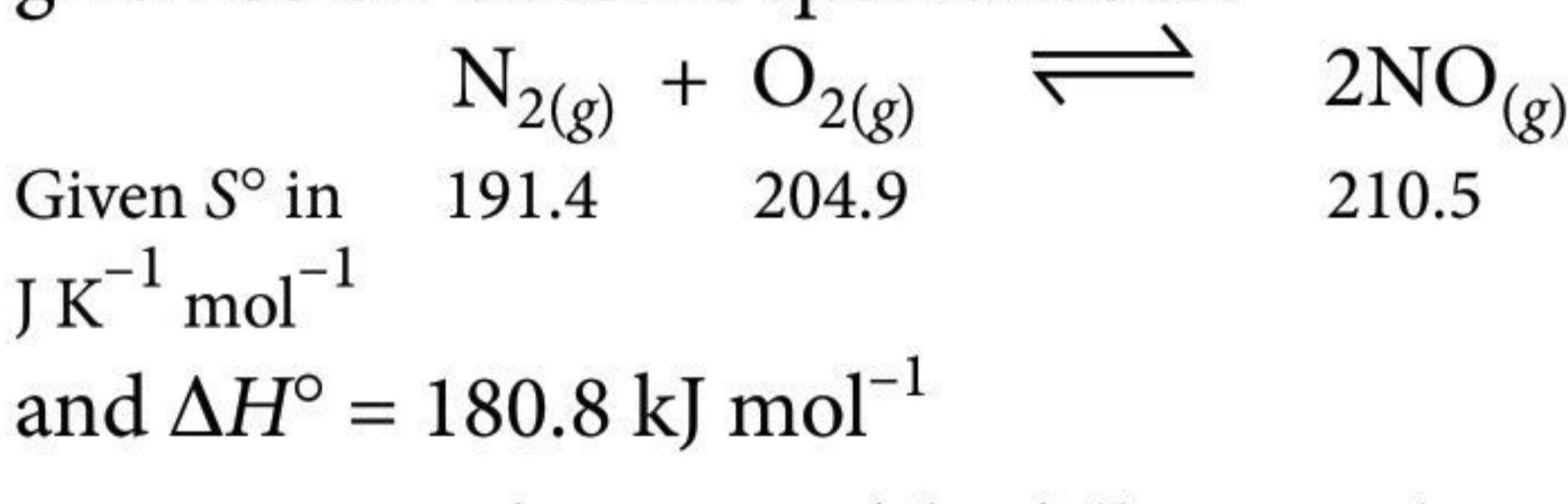
29. A heated copper block at 130°C loses 340 J of heat to the surroundings which are at room temperature of 32°C. Calculate

(i) the entropy change of the system (copper block)  
(ii) the entropy change in the surroundings  
(iii) the total entropy change in the universe due to this process.

Assuming that the temperature of the block and the surroundings remains constant.

**OR**

Assume  $\Delta H^\circ$  and  $\Delta S^\circ$  to be independent of temperature, at what temperature will the reaction given below become spontaneous?



30. Given reason for any 3 of the following observations:  
(i) Can  $q$  become a state function?  
(ii) Why is increase in entropy of the system greater for vaporisation of a substance than for its melting?  
(iii) Reaction with  $\Delta G^\circ < 0$  always have an equilibrium constant greater than 1. Explain why.  
(iv) Dissolving of  $\text{NH}_4\text{Cl}$  in water at room temperature is an endothermic process. Even then it occurs spontaneously, what makes it possible?

### SECTION D

The following questions are case-based questions. Each question has an internal choice and carries 4 (1+1+2) marks each. Read the passage carefully and answer the questions that follow.

31. A thermodynamically irreversible process is always accompanied by an increase in the entropy of the system and its surroundings taken together while in a thermodynamically reversible process, the entropy of the system and its surrounding taken together remain unchanged, i.e., for reversible process,  $\Delta S_{\text{sys}} + \Delta S_{\text{surr}} = 0$  and for irreversible process,  $\Delta S_{\text{sys}} + \Delta S_{\text{surr}} > 0$   
combining the two we have,  $\Delta S_{\text{sys}} + \Delta S_{\text{surr}} \geq 0$

where 'equal to' sign refers to a reversible process while the 'greater than' sign refers to an irreversible process.

Change in entropy for an ideal gas under different conditions may be calculated as

$$\Delta S = 2.303 nR \log_{10} \frac{V_2}{V_1} = 2.303 nR \log_{10} \frac{P_1}{P_2}$$

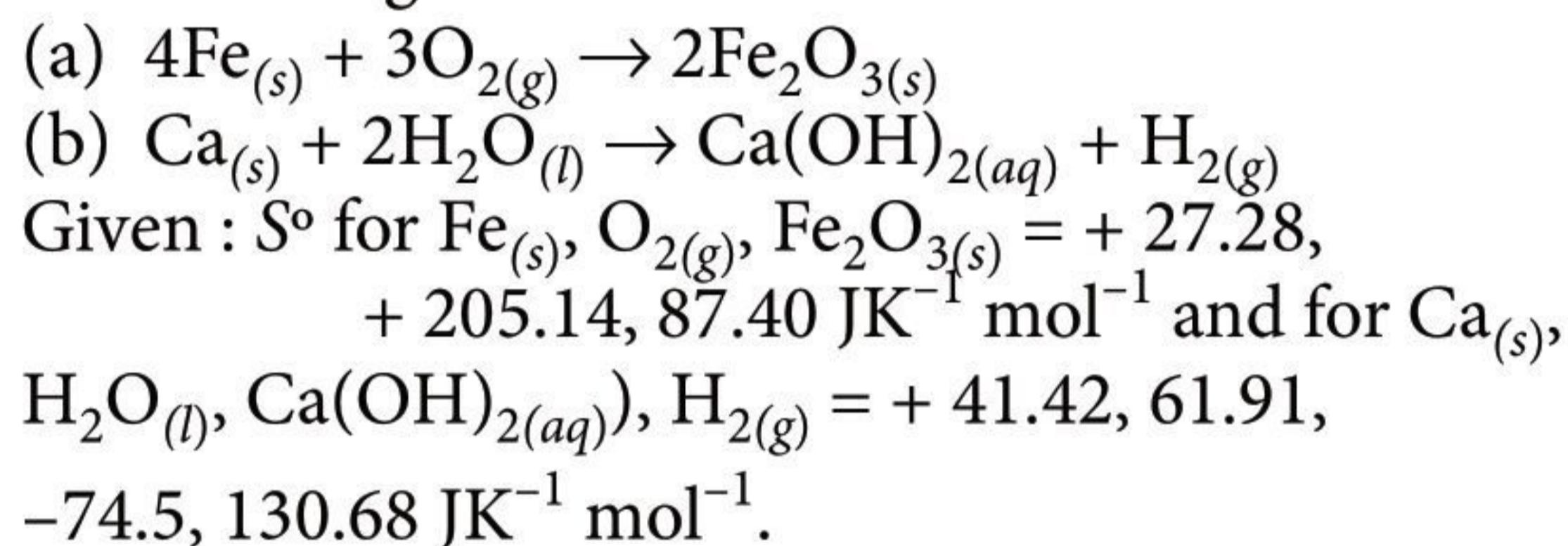
(for isothermal process)

**Answer the following questions:**

(i) Entropy changes for the process,  $\text{H}_2\text{O}_{(l)} \rightarrow \text{H}_2\text{O}_{(s)}$ , at normal pressure and 274 K are given below  $\Delta S_{\text{system}} = -22.13$ ,  $\Delta S_{\text{surr}} = +22.05$ , whether the process is spontaneous or non-spontaneous, explain. ('surr' stands for surrounding and 'u' stands for universe)

(ii) One mole of an ideal gas at 27°C is allowed to expand from 1 litre to 10 litres. Calculate the change in entropy,  $R = 1.99$  cals.

(iii) Calculate the standard molar entropy change for the following reaction at 298 K.

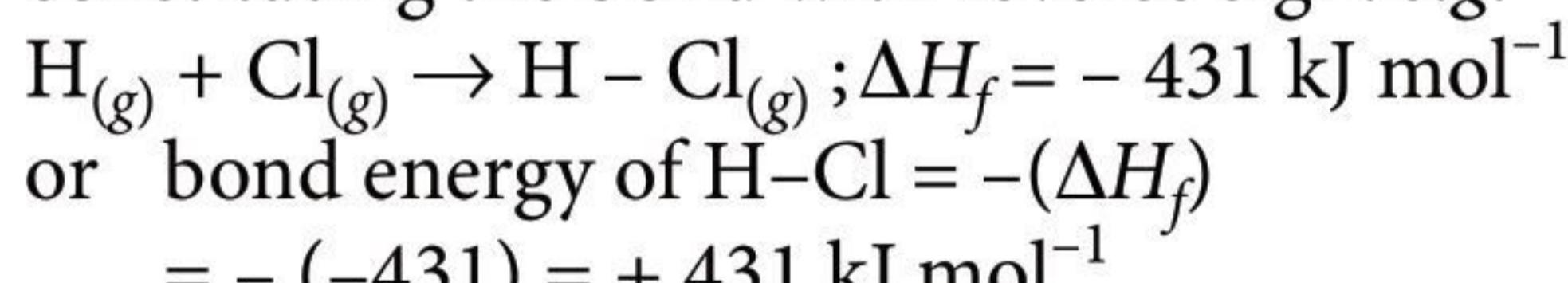


**OR**

Which of the following processes are accompanied by an increase of entropy?

(a) Dissolution of iodine in a solvent  
 (b) HCl is added to  $\text{AgNO}_3$  solution and precipitate of  $\text{AgCl}$  is obtained

32. The bond dissociation energy of a diatomic molecule is also called bond energy. However the bond dissociation energy depends upon the nature of bond and also the molecule in which the bond is present. Bond energy is also called, the heat of formation of the bond from gaseous atoms constituting the bond with reverse sign. e.g.



When a compound shows resonance, there occurs a fair agreement between the calculated values of heat of formation obtained from bond enthalpies and any other method.

However, there occurs large deviations in case of

compounds having alternate single and double bonds.

Resonance energy = Experimental heat of formation - Calculated heat of formation.

**Answer the following questions :**

(i) Calculate the bond dissociation energy of C—H in  $\text{CH}_4$  from the equation  $\text{C}_{(g)} + 4\text{H}_{(g)} \rightarrow \text{CH}_{4(g)}$ ;  $\Delta H = -397.8 \text{ kcal}$

(ii) The bond dissociation energies of  $\text{H}_{2(g)}$ ,  $\text{Cl}_{2(g)}$  and  $\text{HCl}_{(g)}$  are 104, 58 and 103  $\text{kcal mol}^{-1}$  respectively. Calculate the enthalpy of formation of  $\text{HCl}_{(g)}$ .

(iii) The bond enthalpy of  $\text{H}_{2(g)}$  is 436  $\text{kJ mol}^{-1}$  and that of  $\text{N}_{2(g)}$  is 941.3  $\text{kJ mol}^{-1}$ . Calculate the average bond enthalpy of an N—H bond in ammonia  $\Delta H_f^\circ$  ( $\text{NH}_3$ ) = - 46.0  $\text{kJ mol}^{-1}$ .

**OR**

If (i)  $\Delta H_f^\circ$  (benzene) = - 358.5  $\text{kJ mol}^{-1}$   
 (ii) heat of atomisation of graphite = 716.8  $\text{kJ mol}^{-1}$   
 (iii) bond energy of C—H, C—C, C=C and H—H bonds are 490, 340, 620 and 436.9  $\text{kJ mol}^{-1}$  respectively. The resonance energy (in  $\text{kJ mol}^{-1}$ ) of benzene using kekule formula is.

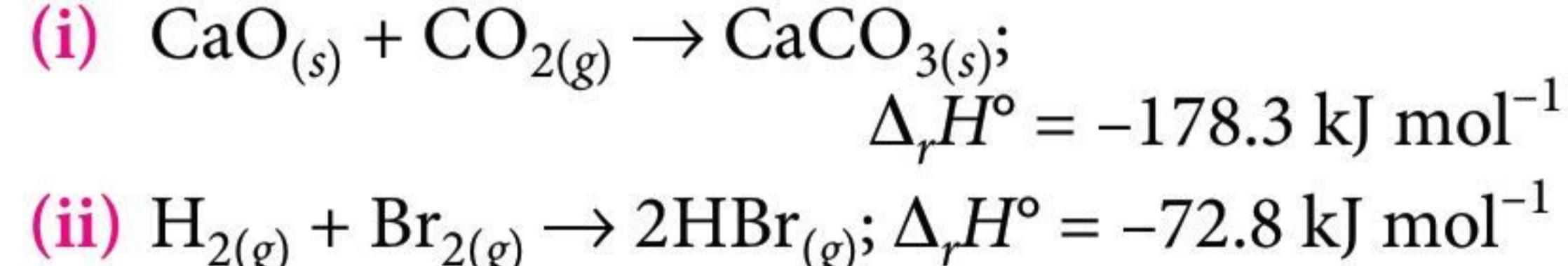
**SECTION E**

**The following questions are long answer type and carry 5 marks each. Two questions have an internal choice.**

33. (a) Calculate the standard enthalpy ( $\Delta_r H^\circ$ ) of the reaction,  $2\text{NO}_{(g)} + \text{O}_{2(g)} \rightarrow 2\text{NO}_{2(g)}$   
 The enthalpy of formation are given :  $\Delta_f H^\circ(\text{NO}_{(g)}) = 90.37 \text{ kJ mol}^{-1}$ ,  $\Delta_f H^\circ(\text{NO}_{2(g)}) = 33.85 \text{ kJ mol}^{-1}$

(b) Calculate the standard enthalpy for the reaction,  $2\text{H}_2\text{S}_{(g)} + 3\text{O}_{2(g)} \rightarrow 2\text{H}_2\text{O}_{(l)} + 2\text{SO}_{2(g)}$   
 Given :  $\Delta_f H^\circ(\text{H}_2\text{O}_{(l)}) = -286.0 \text{ kJ mol}^{-1}$ ,  $\Delta_f H^\circ(\text{SO}_{2(g)}) = -296.9 \text{ kJ mol}^{-1}$ ,  $\Delta_f H^\circ(\text{H}_2\text{S}_{(g)}) = -20.17 \text{ kJ mol}^{-1}$

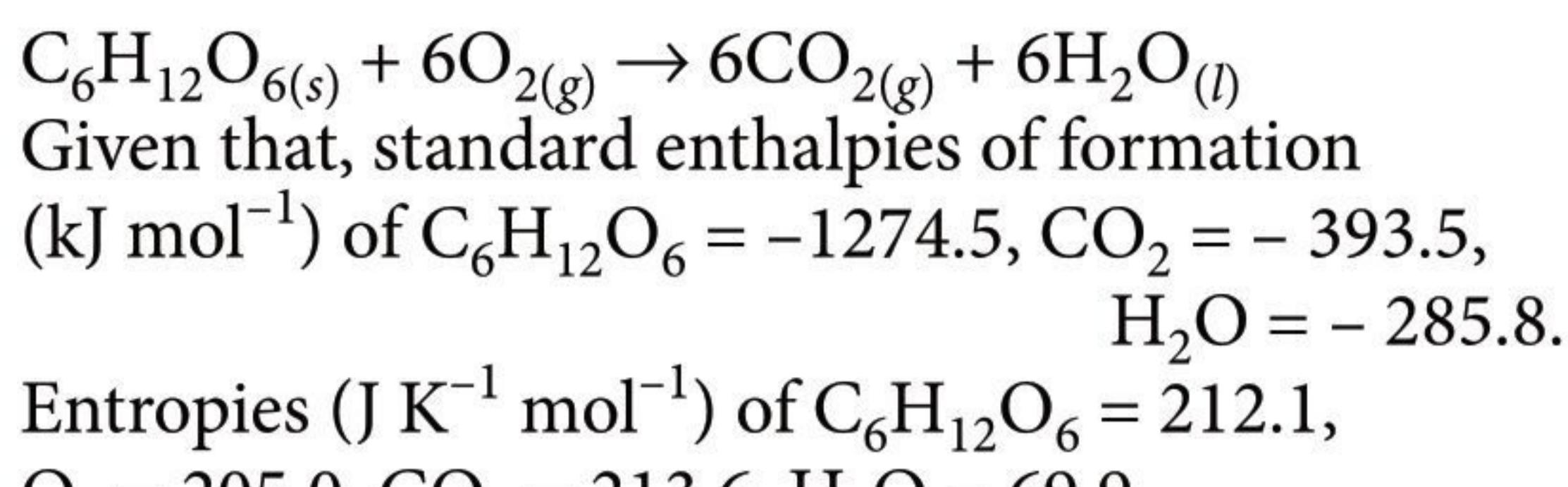
(c) Explain why the enthalpy changes for the given reactions are not enthalpies of formation of  $\text{CaCO}_3$  and  $\text{HBr}$ .



**OR**

(a) What is a bomb calorimeter?  
 (b) (i) Define heat capacity of the system.  
 (ii) Calculate the difference between  $C_p$  and  $C_v$  for 10 moles of an ideal gas.  
 (c) Derive the relation  $C_p - C_v = R$ .

34. (a) Calculate the standard Gibbs energy change for the combustion of  $\alpha$ -D glucose at 298 K



(b) The melting point of ice is 273 K. At this temperature the enthalpy of fusion of ice is 6.025 kJ mol<sup>-1</sup>. Calculate the entropy change for melting of 1 mole of ice. State giving reason, whether the entropy change for vaporization of one mole of water will be more or less than entropy change per mole for fusion of ice.

(c) Calculate the entropy change involved in the conversion of one mole of liquid water at 373 K to vapour at the same temperature (Latent heat of vaporization,  $\Delta H_{\text{vap}} = 2.257 \text{ kJ/g}$ ).

(d) Why does entropy of a solid increases on fusion?

**OR**

(a) State the thermodynamic conditions of spontaneous occurrence of a process.

(b) Express the change in internal energy of the system when no work is done on the system, but  $q$  amount of heat is taken out from the system and given to the surroundings. What type of walls does the system have?

(c) Give reason for the following : Neither  $q$  nor  $w$  is a state function but  $(q + w)$  is a state function.

(d) Calculate the work done when a gas is irreversibly compressed by a pressure of 0.50 atm to decrease its volume from 400 cm<sup>3</sup> to 200 cm<sup>3</sup>.

35. (a) The enthalpy of vapourisation of liquid ether at its boiling point (35°C) is 26 kJ/mol. Calculate the entropy change for liquid ether to its vapour state.

(b) At what temperature will the following reaction be spontaneous?  $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$   
 (Given :  $\Delta H = -95.4 \text{ kJ/mol}$  and  $\Delta S = -198.3 \text{ J/K}$ )

(c) What are path functions? Give example.

(d) Why a non-spontaneous reaction becomes spontaneous when coupled with a suitable spontaneous reaction?

(e) For an isolated system,  $\Delta U = 0$ , what will be  $\Delta S$ ?

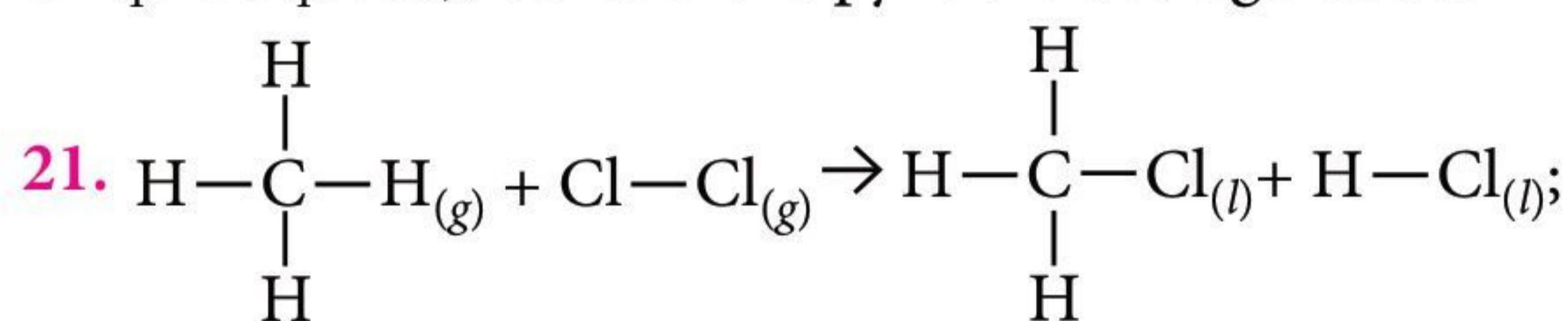
**19. (i)** Both energy factor and randomness factor favour the process. Hence, reaction will always be spontaneous.

**(ii)** Energy factor opposes but randomness factor favours. For spontaneity,  $T\Delta S > \Delta H$ . Hence, reaction is spontaneous at high temperature and non-spontaneous at low temperature.

**20. (a)** Under ordinary conditions, the average energy of the reactants may be less than the threshold energy. They require some activation energy to initiate the reaction.

$$\Delta G = \Delta H - T\Delta S$$

At lower temperature, if value of  $\Delta H$  is negative,  $\Delta G$  will be -ve and if  $\Delta H$  is positive,  $\Delta G$  will be positive. While at higher temperature  $-T\Delta S$  will be high, thus, sign of  $\Delta S$  will decide whether  $\Delta G$  will be positive or negative. Bond enthalpy is the amount of energy released when gaseous atoms combine to form one mole of bonds between them [(e.g.,  $\text{H} + \text{H} \rightarrow \text{H}_2$ )]. Bond dissociation enthalpy is the amount of heat absorbed when one mole of bonds present between atoms in the gaseous molecules are broken to give free gaseous atoms (e.g.,  $\text{H}_2 \rightarrow \text{H} + \text{H}$ ). The bond enthalpy and bond dissociation enthalpy for a bond are equal in magnitude but opposite in sign. For polyatomic molecules (e.g.,  $\text{CH}_4$ ,  $\text{CCl}_4$ , etc.), bond enthalpy is the average value.



$$\Delta H = -100.3 \text{ kJ mol}^{-1}$$

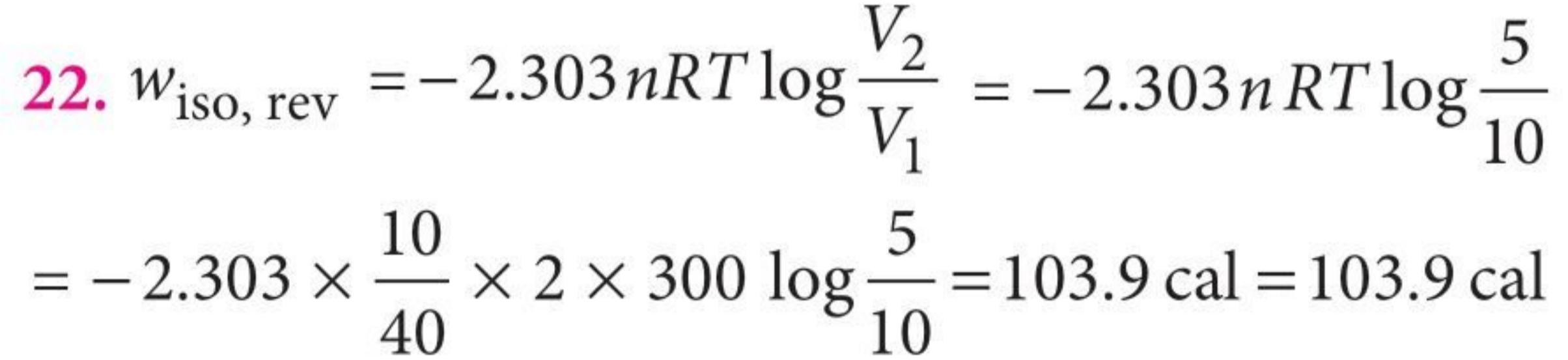
Enthalpy of reaction = Bond energy (reactants) - Bond energy (products)

$$\Delta H = [4 \times \text{B.E.}(\text{C}-\text{H}) + \text{B.E.}(\text{Cl}-\text{Cl})] - [3 \times \text{B.E.}(\text{C}-\text{H}) + \text{B.E.}(\text{C}-\text{Cl}) + \text{B.E.}(\text{H}-\text{Cl})]$$

$$\Delta H = \text{B.E.}(\text{C}-\text{H}) + \text{B.E.}(\text{Cl}-\text{Cl}) - \text{B.E.}(\text{C}-\text{Cl}) - \text{B.E.}(\text{H}-\text{Cl})$$

$$-100.3 = 413 + \text{B.E.}(\text{Cl}-\text{Cl}) - 326 - 431$$

$$\text{B.E.}(\text{Cl}-\text{Cl}) = -100.3 + 326 + 431 - 413 = 243.7 \text{ kJ mol}^{-1}$$

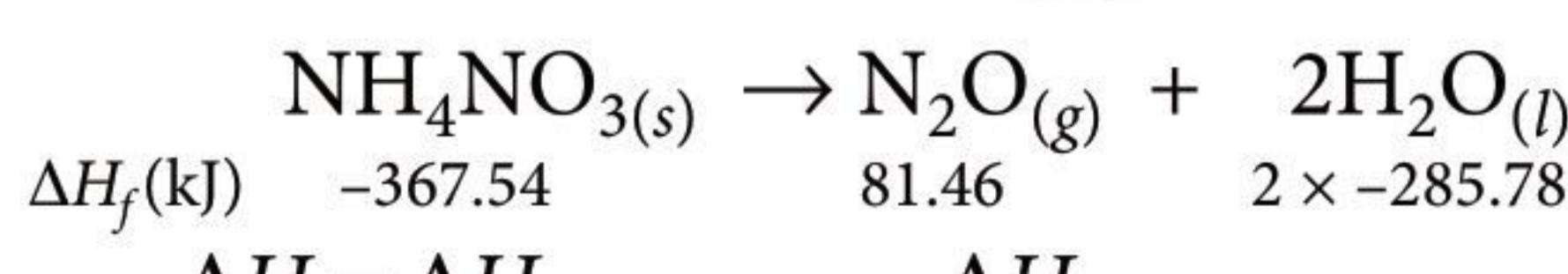


For isothermal process,  $\Delta U = 0$

From 1<sup>st</sup> law of thermodynamics,  $\Delta U = q + W$

$$\therefore q = -W = -103.9 \text{ cal}$$

**OR**



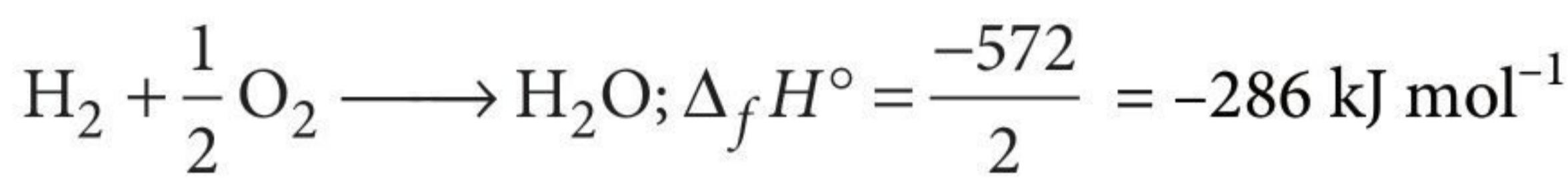
$$\Delta H = \Delta H_f(\text{Products}) - \Delta H_f(\text{Reactants})$$

### SOLUTIONS

1. (c)	2. (d)	3. (a)	4. (d)
5. (a)	6. (c)	7. (b)	8. (d)
9. (a)	10. (b)	11. (d)	12. (a)
13. (b)	14. (c)	15. (a)	16. (c)
17. (c)	18. (a)		

$$\begin{aligned}
 &= [2 \times (-285.78) + 81.46] - (-367.54) \\
 &= -122.56 \text{ kJ} = -122.56 \times 10^3 \text{ J} \\
 \Delta n_g &= n_p - n_r = 1 - 0 = 1 \\
 \Delta H &= \Delta U + \Delta n_g RT \Rightarrow \Delta U = \Delta H - \Delta n_g RT \\
 \Delta U &= -122.56 \times 10^3 - 1 \times 8.314 \times 298 \\
 &= -125.04 \times 10^3 \text{ J} = -125.04 \text{ kJ}
 \end{aligned}$$

23.  $2\text{H}_2 + \text{O}_2 \longrightarrow 2\text{H}_2\text{O}$ ;  $\Delta_f H^\circ = 572 \text{ kJ mol}^{-1}$   
 $\Delta_f H^\circ$  will be half of the enthalpy of the given equation as enthalpy of formation is the enthalpy change of the reaction when 1 mole of the compound is formed from its elements.



OR

At equilibrium,  $\Delta G = 0$   
 Since,  $\Delta G = \Delta H - T\Delta S$ , so at equilibrium

$$T = \frac{\Delta H}{\Delta S} = \frac{-10000}{-33.3} = 300.3 \text{ K}$$

(i) For left to right spontaneity,  $\Delta G$  should be negative. For  $\Delta G$  to be negative, temperature must be less than 300.3 K i.e.,  $T < 300.3 \text{ K}$ .

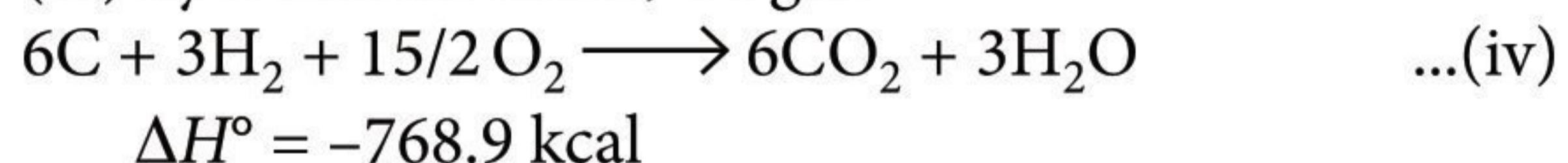
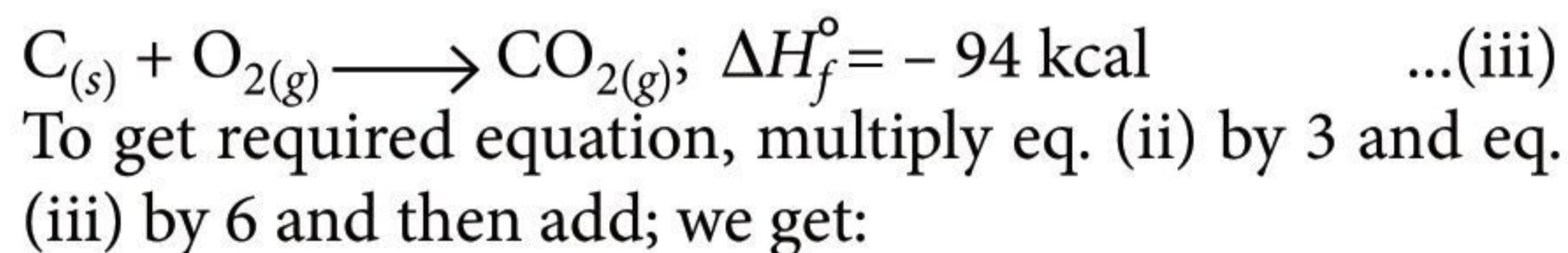
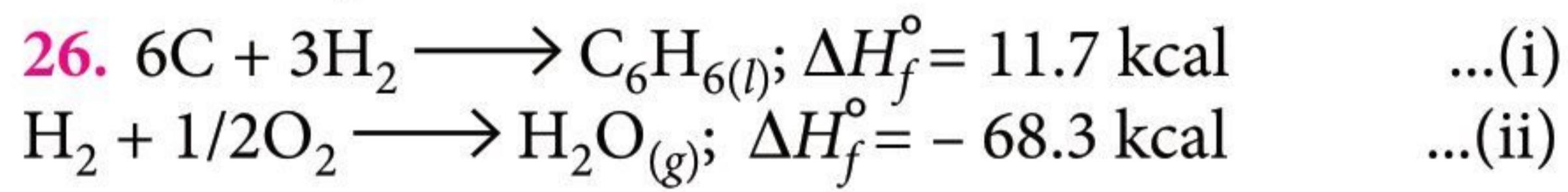
(ii) For reverse reaction i.e., right to left spontaneity,  $\Delta G$  should be positive. For  $\Delta G$  to be positive, temperature must be more than 300.3 K i.e.,  $T > 300.3 \text{ K}$ .

24. (a) The balanced chemical equation which includes the amount of heat evolved or absorbed during the reaction is called a thermochemical equation.

(b) Hess's law is found very useful in calculating the enthalpy change for the reaction for which experimental determination is not possible.

25. Molar enthalpy change for graphite ( $\Delta H$ )  
 = enthalpy change for 1 g  $\times$  molar mass of C  
 $= -20.7 \times 12 = -2.48 \times 10^2 \text{ kJ mol}^{-1}$

Since the sign of  $\Delta H$  = -ve, it is an exothermic reaction.



Subtract eq. (i) from (iv), we get:  
 $\text{C}_6\text{H}_6 + 15/2\text{O}_2 \longrightarrow 6\text{CO}_2 + 3\text{H}_2\text{O}; \Delta H^\circ = -780.6 \text{ k cal}$

78 g  $\text{C}_6\text{H}_6$  gives heat = 780.6 kcal

$$\therefore 1000 \text{ g } \text{C}_6\text{H}_6 \text{ will give heat} = \frac{780.6 \times 1000}{78} = 10007.7 \text{ kcal/mol}$$

$$\begin{aligned}
 &\text{Heat liberated by burning 1 kg benzene} \\
 &\quad = 10007.7 \text{ k cal/mol}
 \end{aligned}$$

27. The first law of thermodynamics is simply the law of conservation of energy which states that energy can neither be created nor be destroyed although it may be converted from one form to another.

The internal energy of a system can be increased in two ways : (i) By supplying heat to the system, (ii) By doing work on the system.

Let, initial internal energy of the system =  $U_1$   
 If it absorbs heat  $q$ , its internal energy will become  $= U_1 + q$

If further work,  $w$  is done on the system, the internal energy will further increase and become  $= U_1 + q + w$   
 Let us call this final internal energy as  $U_2$ ,

Then,  $U_2 = U_1 + q + w$  or  $U_2 - U_1 = q + w$  or  $\Delta U = q + w$   
 This equation is the mathematical formulation of the first law of thermodynamics.

28. Mass of water = 125 g

Change in temperature =  $286.4 \text{ K} - 296.5 \text{ K} = -10.1 \text{ K}$

Specific heat capacity of water is  $4.184 \text{ J g}^{-1}\text{K}^{-1}$

Heat capacity of calorimeter and its contents

$$= 125 \text{ g} \times 4.184 \text{ J g}^{-1}\text{K}^{-1} = 125 \times 4.184 \text{ J K}^{-1}$$

$q$  = Heat capacity of calorimeter and its contents  $\times$  change in temperature

$$= 125 \times 4.184 \text{ J K}^{-1} \times (-10.1 \text{ K}) = -5282.3 \text{ J} = -5.28 \text{ kJ}$$

The -ve sign before the value means, heat is lost by the calorimeter and its contents.

29.  $T_{\text{system}} = 130^\circ\text{C} = 130 + 273 \text{ K} = 403 \text{ K}$ ,

$$T_{\text{surr}} = 32^\circ\text{C} = 32 + 273 \text{ K} = 305 \text{ K}$$

$$q_{\text{system}} = -340 \text{ J}, q_{\text{surr}} = +340 \text{ J}$$

(i)  $\Delta S_{\text{system}} = \frac{q_{\text{system}}}{T_{\text{system}}} = \frac{-340 \text{ J}}{403 \text{ K}} = -0.84 \text{ J K}^{-1}$

(ii)  $\Delta S_{\text{surr}} = \frac{q_{\text{surr}}}{T_{\text{surr}}} = \frac{+340 \text{ J}}{305 \text{ K}} = +1.11 \text{ J K}^{-1}$

(iii)  $\Delta S_{\text{total}} \text{ or } \Delta S_{\text{universe}} = \Delta S_{\text{system}} + \Delta S_{\text{surr}}$   
 $= -0.84 + (+1.11) \text{ J K}^{-1} = 0.27 \text{ J K}^{-1}$

OR

$$\begin{aligned}
 \text{As } \Delta S^\circ &= S^\circ_{\text{Product}} - S^\circ_{\text{Reactant}}; \Delta S^\circ = (2S^\circ_{\text{NO}}) - (S^\circ_{\text{N}_2} + S^\circ_{\text{O}_2}) \\
 &= 2 \times 210.5 - (191.4 + 204.9) \\
 &= 24.7 \text{ J K}^{-1} \text{ mol}^{-1} = 24.7 \times 10^{-3} \text{ kJ K}^{-1} \text{ mol}^{-1}
 \end{aligned}$$

Since  $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

$$\Delta G^\circ = 180.8 - (T \times 24.7 \times 10^{-3}) \text{ kJ mol}^{-1}$$

For a spontaneous process  $\Delta G^\circ$  should be -ve which is possible if

$$T\Delta S^\circ > \Delta H^\circ; T > \frac{\Delta H^\circ}{\Delta S^\circ}; T > \frac{180.8 \times 10^3}{24.7} = 7319 \text{ K}$$

The reaction becomes spontaneous above the temperature of 7320 K.

**30. (i)** Heat exchange reversible at constant volume (or at constant pressure) is equal to the change in internal energy (or enthalpy) of a system. Since the latter is a state function, it follows that in such conditions  $q$  also behaves like a state function.

**(ii)** More disorder is associated with the formation of a gas because of the large volume of expansion and increased freedom for motion.

**(iii)** Relation between  $\Delta G^\circ$  and equilibrium constant is given as  $\Delta G^\circ = -2.303 RT \log K$ .

From the above relation it is clear that for  $K = 1$ ,  $\log K$  will become 0 and  $\Delta G$  will also become zero (i.e., system will be at equilibrium). Therefore, if the value of  $\Delta G^\circ$  is negative i.e.,  $\Delta G^\circ < 0$  the value of  $K$  should be greater than one.

**(iv)** For a spontaneous reaction  $\Delta G = (\Delta H - T\Delta S)$  should be negative. On dissolving  $\text{NH}_4\text{Cl}$  in water it dissociates into ions, hence the randomness of the system increases and hence the value of entropy increases. Thus, the value of  $T\Delta S$  (-ve) becomes more than the value of  $\Delta H$  (+ve) to give the negative value of  $\Delta G$ .

$$\begin{aligned} \text{(i)} \Delta S_s &= \Delta S_{\text{system}} + \Delta S_{\text{surrounding}} \geq 0 \\ &= -22.13 + 22.05 = -0.08 \end{aligned}$$

As the  $\Delta S$  is negative. So the process is non-spontaneous.

**(ii)** For isothermal expansion of an ideal gas  $\Delta S$  is given as

$$\Delta S = 2.303 nR \log_{10} \frac{V_2}{V_1}$$

Substituting the values given, we have

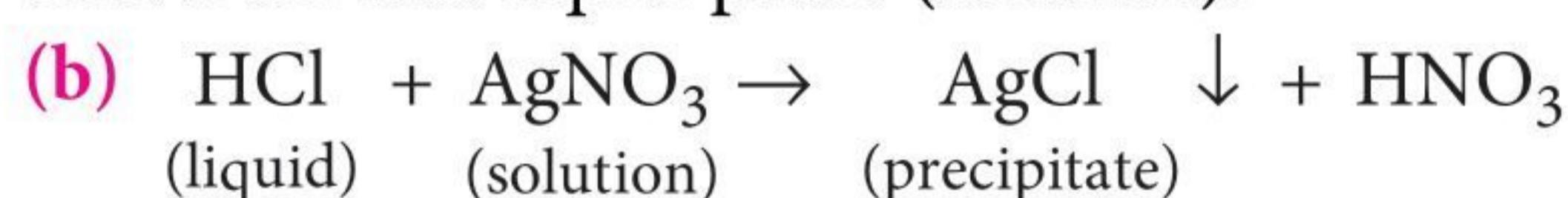
$$\Delta S = 2.303 \times 1 \times 2 \times \log_{10} \frac{10}{1} = 4.606 \text{ cal/deg/mol.}$$

$$\begin{aligned} \text{(iii) (a)} \Delta S^\circ_m &= [2 \times S^\circ \text{Fe}_2\text{O}_3] - [4 \times S^\circ \text{Fe} + 3 \times S^\circ \text{O}_2] \\ &= (2 \times 87.40) - (4 \times 27.28 + 3 \times 205.14) \\ &= -549.74 \text{ JK}^{-1} \text{ mol}^{-1} \end{aligned}$$

$$\begin{aligned} \text{(b)} \Delta S^\circ_m &= [S^\circ \text{Ca}(\text{OH})_2 + S^\circ \text{H}_2] - [S^\circ \text{Ca} + 2S^\circ \text{H}_2\text{O}] \\ &= [-74.5 + 130.68] - [41.42 + 2 \times 61.91] \\ &= 109.06 \text{ JK}^{-1} \text{ mol}^{-1} \end{aligned}$$

**OR**

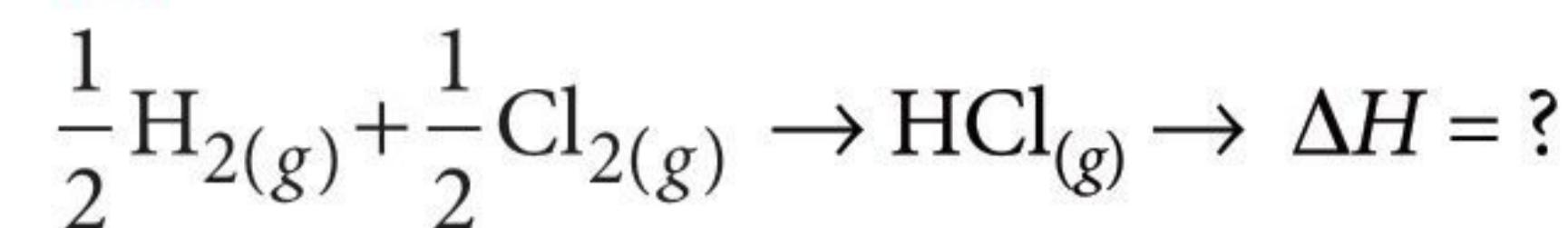
**(a)** Entropy is increased because solid iodine is converted into liquid phase (solution).



In this reaction liquid HCl is mixed with the solution of  $\text{AgNO}_3$  and the formation of  $\text{AgCl}(\text{ppt})$  occurs hence entropy is decreased.

**32. (i)** Bond energy  $= -(\Delta H_f) = -(-397.8) \text{ kcal}$   
 $= +397.8 \text{ kcal}$  as there are 4C-H bond in methane  
 therefore B.E. of C - H  $= 397.8/4 = 99.45 \text{ kcal}$

**(ii)** We have to find



as  $\Delta H = \text{B.E. of reactant} - \text{B.E. of product}$

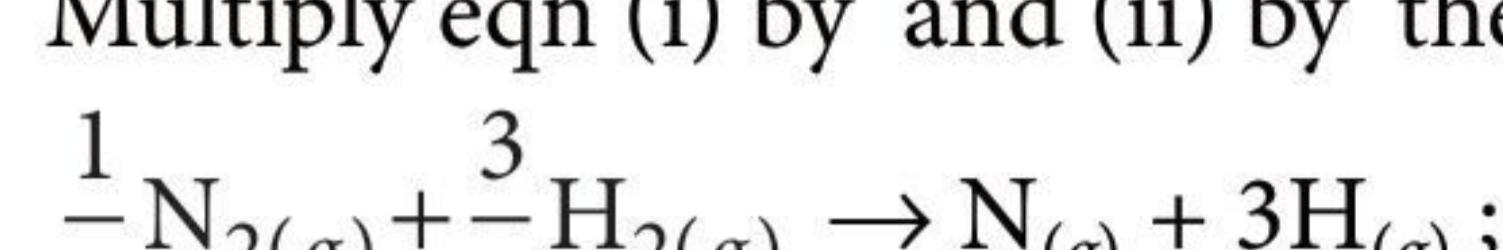
$$= 1/2 \times 104 + 1/2 \times 58 - 103 = -22 \text{ kcal mol}^{-1}$$

$$\text{(iii)} \text{Given } \text{N}_{2(g)} \rightarrow 2\text{N}_{(g)}; \Delta H^\circ = 941.3 \text{ kJ mol}^{-1} \quad \dots \text{(i)}$$

$$1/2 \text{H}_{2(g)} \rightarrow \text{H}_{(g)}; \Delta H^\circ = 436.0 \text{ kJ mol}^{-1} \quad \dots \text{(ii)}$$

$$\text{N}_{2(g)} + \text{H}_{2(g)} \rightarrow \text{NH}_{3(g)}; \Delta H^\circ = -461 \text{ kJ mol}^{-1} \quad \dots \text{(iii)}$$

Multiply eqn (i) by 2 and (ii) by 3 then add, we get



$$\Delta H^\circ = 941.3 \times \frac{1}{2} + 436.0 \times \frac{3}{2} \quad \dots \text{(iv)}$$

$$= 470.65 + 654 = 1124.65 \text{ kJ mol}^{-1}$$

Now subtract eqn (iii) for eqn (iv) we get

$$\begin{aligned} \text{NH}_3 \rightarrow \text{N}_{(g)} + 3\text{H}_{(g)}; \Delta H^\circ &= 1124.6 - (-46.0) \text{ kJ mol}^{-1} \\ &= 1170.65 \text{ kJ mol}^{-1} \end{aligned}$$

Since there are three N-H bonds in  $\text{NH}_3$ , the average bond enthalpy is obtained by dividing the value of  $\Delta H^\circ$  by 3.

**OR**

From the reaction



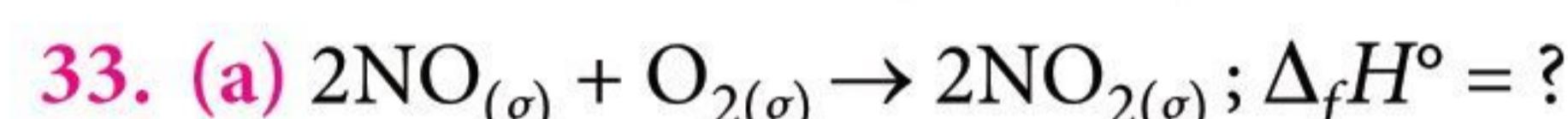
$\Delta H_f$  can be calculated as

$$\Delta H_f(\text{C}_6\text{H}_6) = [6 \times \Delta H_{\text{C}_{(s)} \rightarrow \text{C}_{(g)}} + 3 \times \Delta H_{\text{H-H}}]$$

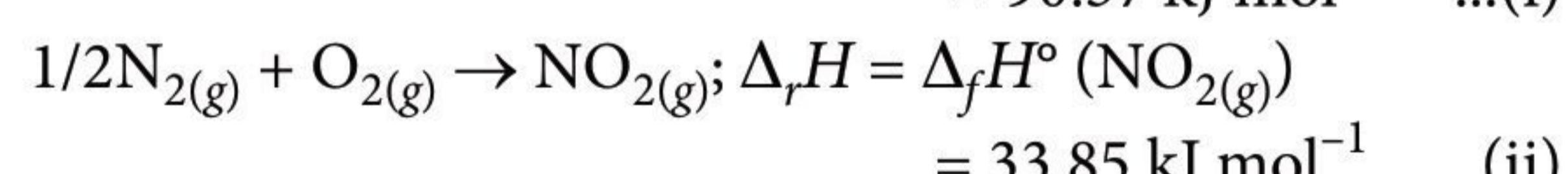
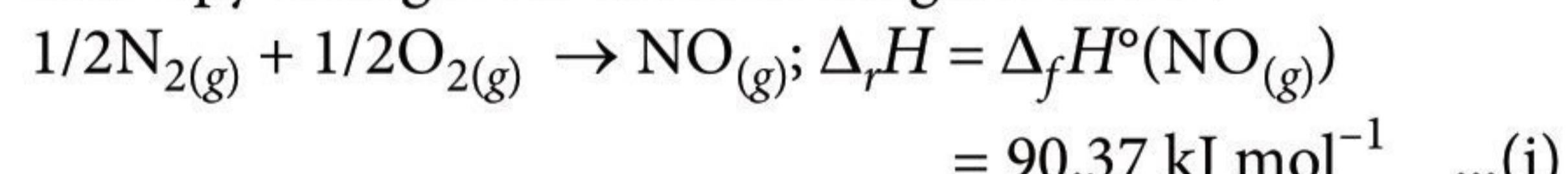
$$\begin{aligned} &- [3 \times \text{B.E. of C-C} + 3 \times \text{B.E. of C-C} + 6 \times \text{B.E. of C-H}] \\ &= [6 \times 716.8 + 3 \times 436.9] - [3 \times 340 + 3 \times 620 + 6 \times 490] \end{aligned}$$

$$= -208.5 \text{ kJ mol}^{-1}$$

$$\begin{aligned} \Delta H_{\text{resonance}} &= \Delta H_f(\text{exp}) - \Delta H_f(\text{calculated}) \\ &= -358.5 - (-208.5) = -150.0 \text{ kJ mol}^{-1} \end{aligned}$$



The given enthalpies of formation, correspond to the enthalpy changes for the following reactions :



Multiplying eq (ii)  $\times 2$  - eq (i)  $\times 2$ , we get,

$$\Delta_r H^\circ = (2 \times 33.85) - (2 \times 90.37)$$

$$\Delta_r H^\circ = (67.70 - 180.74) \text{ kJ mol}^{-1} = -113.04 \text{ kJ mol}^{-1}$$

$$\text{(b)} \Delta_r H^\circ = \sum \Delta_f H^\circ(\text{products}) - \sum \Delta_f H^\circ(\text{reactants})$$

$$\begin{aligned} &= [2 \times \Delta_f H^\circ(\text{H}_2\text{O}_{(l)}) + 2 \times \Delta_f H^\circ(\text{SO}_{2(g)})] \\ &\quad - [2 \times \Delta_f H^\circ(\text{H}_2\text{S}_{(g)}) + 3 \times \Delta_f H^\circ(\text{O}_2)] \\ &= [2 \times (-286.0) + 2 \times (-296.9)] \text{ kJ mol}^{-1} \\ &\quad - [2 \times (-20.17)] \text{ kJ mol}^{-1} \end{aligned}$$

$$\begin{aligned} \text{Therefore, } \Delta_r H^\circ &= [-572 - 593.8] \text{ kJ mol}^{-1} - [40.34] \text{ kJ mol}^{-1} \\ &= -1206.14 \text{ kJ mol}^{-1} \end{aligned}$$

(c) (i) Given enthalpy change is not enthalpy of formation of  $\text{CaCO}_3$ , because it is not being formed from constituent elements.

(ii) Given enthalpy change is not enthalpy of formation of  $\text{HBr}$  because 2 moles of  $\text{HBr}$  are being formed

OR

(a) A bomb calorimeter is used to measure the internal energy change ( $\Delta U$ ) when one mole of a substance is completely burnt in oxygen using an apparatus called bomb calorimeter.

(b) (i) Heat capacity of the system is defined as the quantity of heat required to raise the temperature of the system by one degree. this is denoted by  $C_v$  (at constant volume) and  $C_p$  (at constant pressure). So, heat capacity  $= dq/dT$

$$(ii) C_p = C_v + nR \Rightarrow C_p - C_v = 10 R$$

(c) At constant volume as  $q_v = C_v \Delta T = \Delta U$

at constant pressure  $q_p = C_p \Delta T = \Delta H$

For a mole of an ideal gas,  $\Delta H = \Delta U + \Delta(pV)$

$$\therefore \Delta H = \Delta U + R\Delta T$$

On putting the values of  $\Delta H$  and  $\Delta U$

we have  $C_p \Delta T = C_v \Delta T + R\Delta T$

$$C_p = C_v + R \Rightarrow C_p - C_v = R$$

34. (a) As  $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

$$\Delta H_f^\circ = \Delta H_{f(\text{product})}^\circ - \Delta H_{f(\text{reactant})}^\circ$$

$$\therefore \Delta H^\circ = [6\Delta H_f^\circ(\text{CO}_2) + 6\Delta H_f^\circ(\text{H}_2\text{O})] - [\Delta H_f^\circ(\text{C}_6\text{H}_{12}\text{O}_6) + 6\Delta H_f^\circ(\text{O}_2)] \\ = [6 \times (-393.5) + 6 \times (-285.8)] - [(-1274.5) + 6 \times 0] \\ [\Delta H_f^\circ(\text{O}_2) = 0] \\ = -2361.0 - 1714.8 + 1274.5 = -2801.3 \text{ kJ mol}^{-1}$$

$$\text{Similarly, } \Delta S_f^\circ = \Delta S_{(\text{product})}^\circ - \Delta S_{(\text{reactant})}^\circ$$

$$\Delta S_f^\circ = [6\Delta S^\circ(\text{CO}_2) + 6\Delta S^\circ(\text{H}_2\text{O})] - [\Delta S^\circ(\text{C}_6\text{H}_{12}\text{O}_6) + 6\Delta S^\circ(\text{O}_2)] \\ = [6 \times (213.6) + 6 \times (69.9)] - [(212.1) + 6 \times (205.0)] \\ = [1281.6 + 419.4] - [212.1 + 1230] = 258.9 \text{ J K}^{-1} \text{ mol}^{-1}$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$\Delta H^\circ = -2801.3 \text{ kJ mol}^{-1} = 2801300 \text{ J mol}^{-1}$$

$$\Delta S^\circ = 258.9 \text{ J K}^{-1} \text{ mol}^{-1}; T = 298 \text{ K}$$

$$\therefore \Delta G^\circ = -2801300 - 298 \times (258.9) \\ = -2878.4 \text{ kJ mol}^{-1}$$

$$(b) \Delta S_{(\text{fusion})} = \frac{\Delta H_{(\text{fusion})}}{T} = \frac{6025}{273} = 22.07 \text{ J K}^{-1} \text{ mol}^{-1}.$$

The entropy change for the conversion of 1 mole of liquid water to steam at the boiling point will be more as compared to the value at the freezing point, because in the vaporisation randomness increases (due to the

conversion of liquid into vapour) much more than in fusion.

(c) Latent heat of vaporisation per mole  $= 2.257 \times 10^3 \times 18 = 40,626 \text{ J mol}^{-1}$

$$\Delta S_{(\text{vap})} = \frac{\Delta H_{(\text{vap})}}{T} = \frac{40626}{373} = 108.9 \text{ J K}^{-1} \text{ mol}^{-1}$$

(d) In a solid, the constituent particles are fixed. On melting, they fall apart and are free to move, i.e., their randomness increases.

OR

(a) For spontaneous reaction,  $\Delta G$  of process must be  $< 0$  i.e., -ve. This can be done under the following conditions.

(i)  $\Delta H$  is negative and  $\Delta S$  is positive (at any temperature).

(ii) If  $\Delta H$  and  $\Delta S$  both are positive, then  $T$  should be so high that  $T\Delta S < \Delta H$ .

(iii) If both  $\Delta H$  and  $\Delta S$  are negative, then  $T$  should be so low that  $T\Delta S < \Delta H$ .

(b)  $\Delta U = -q$ , thermally conducting walls.

(c)  $\Delta U = q + w$

' $q$ ' and ' $w$ ' are not state functions because they depend upon path.

Since,  $\Delta U$  is a state function and it is equal to  $(q + w)$ , therefore,  $(q + w)$  is state function.

(d) For isothermal irreversible change,

$$q = -w = P_{\text{ex}}(V_f - V_i)$$

$$-w = 0.50 (200-400) \times 10^{-3} \text{ J} \quad -w = 0.50 \times -200 \times 10^{-3} \text{ J}$$

$$\therefore w = 0.1 \text{ litre atm}$$

35. (a) Enthalpy of vapourisation ( $\Delta H$ ) = 26 kJ/mol

Boiling point =  $35^\circ\text{C} = (35 + 273) \text{ K} = 308 \text{ K}$

Now, at constant pressure,

$$\text{Entropy change, } \Delta S = \frac{-\Delta H}{T}; \Delta S = \frac{26 \text{ kJ/mol}}{308 \text{ K}}$$

$$= 0.0844 \text{ kJ mol}^{-1} \text{ K}^{-1}$$

(b)  $\Delta G = \Delta H - T\Delta S$

For the reaction to be spontaneous,  $\Delta G = -\text{ve}$ .  $T\Delta S > \Delta H$

$$T > \frac{\Delta H}{\Delta S} = \frac{-95.4 \times 1000}{-198.3} = 481.1 \text{ K}$$

Thus, temperature should be greater than 481.1 K.

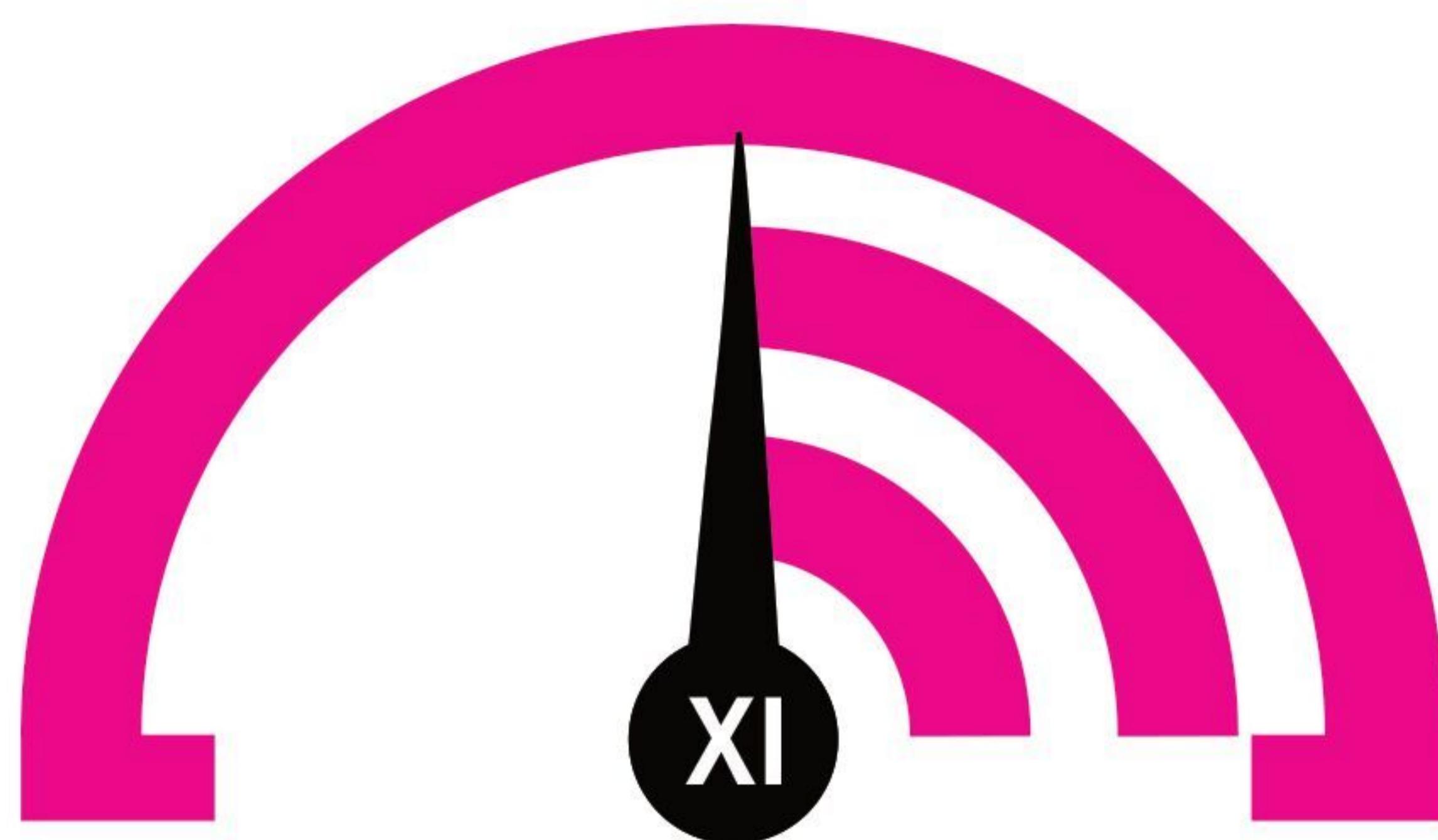
(c) Path functions : These are the functions whose magnitude depends on the path followed during a process as well as on the end states. e.g., work ( $w$ ) and heat ( $q$ ) are path functions.

(d) The overall free energy change of the coupled reaction is negative.

(e) When energy factor has no role to play, for the process to be spontaneous  $\Delta S$  must be +ve i.e.,  $\Delta S > 0$ .



# MONTHLY TEST DRIVE



This specially designed column enables students to self analyse their extent of understanding the specified chapters. Give yourself four marks for correct answer and deduct one mark for wrong answer. Self check table given at the end will help you to check your readiness.

**Total Marks : 120**

## Equilibrium | Redox Reactions

**Time Taken : 60 Min.**

**NEET**

**Only One Option Correct Type**

1.  $3\text{O}_{2(g)} \rightleftharpoons 2\text{O}_{3(g)}$

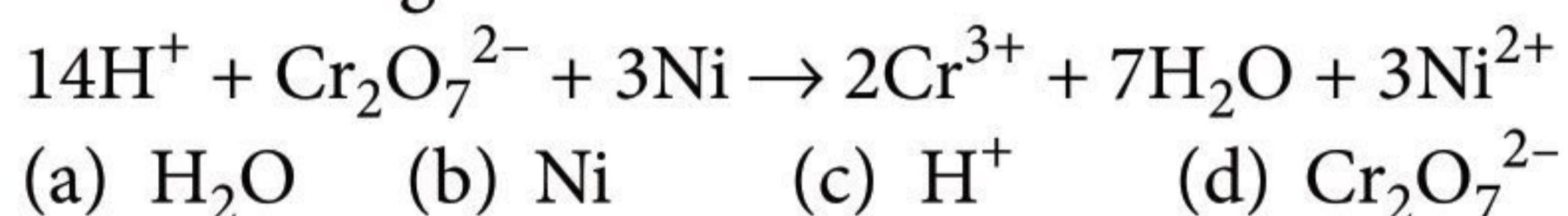
For the above reaction at 298 K,  $K_c$  is found to be  $3.0 \times 10^{-59}$ . If the concentration of  $\text{O}_2$  at equilibrium is 0.040 M then concentration of  $\text{O}_3$  (in M) is

(a)  $4.38 \times 10^{-32}$  (b)  $1.9 \times 10^{-63}$   
 (c)  $2.4 \times 10^{31}$  (d)  $1.2 \times 10^{21}$

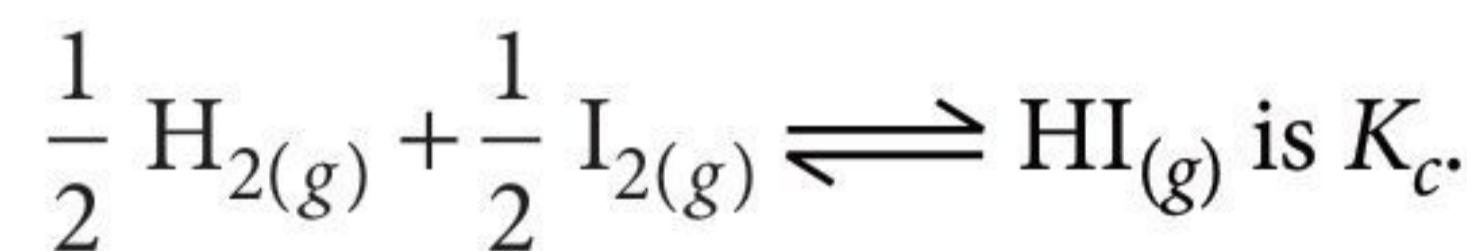
2. In which of the following reactions, the underlined substance has been reduced?

(a)  $\underline{\text{CO}} + \text{CuO} \rightarrow \text{CO}_2 + \text{Cu}$   
 (b)  $\underline{\text{CuO}} + 2\text{HCl} \rightarrow \underline{\text{CuCl}_2} + \text{H}_2\text{O}$   
 (c)  $4\underline{\text{H}_2\text{O}}_{(g)} + 3\text{Fe} \rightarrow 4\underline{\text{H}_2}_{(g)} + \text{Fe}_3\text{O}_4$   
 (d)  $\underline{\text{C}} + 4\text{HNO}_3 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + 4\text{NO}_2$

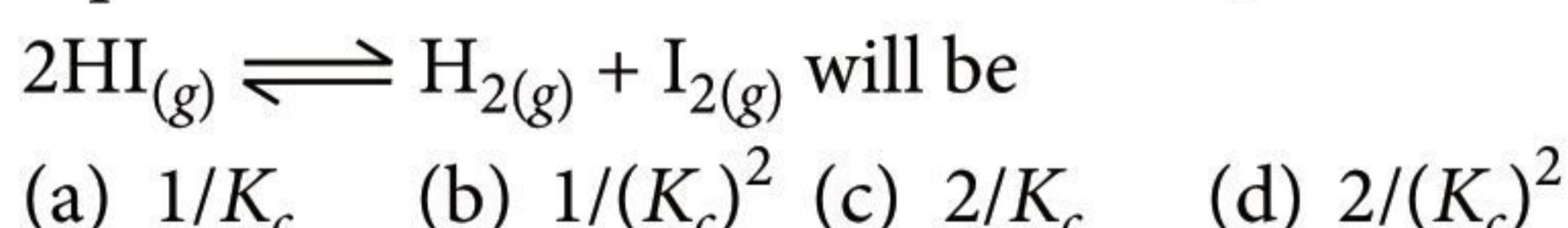
3. Which substance is serving as a reducing agent in the following reaction?



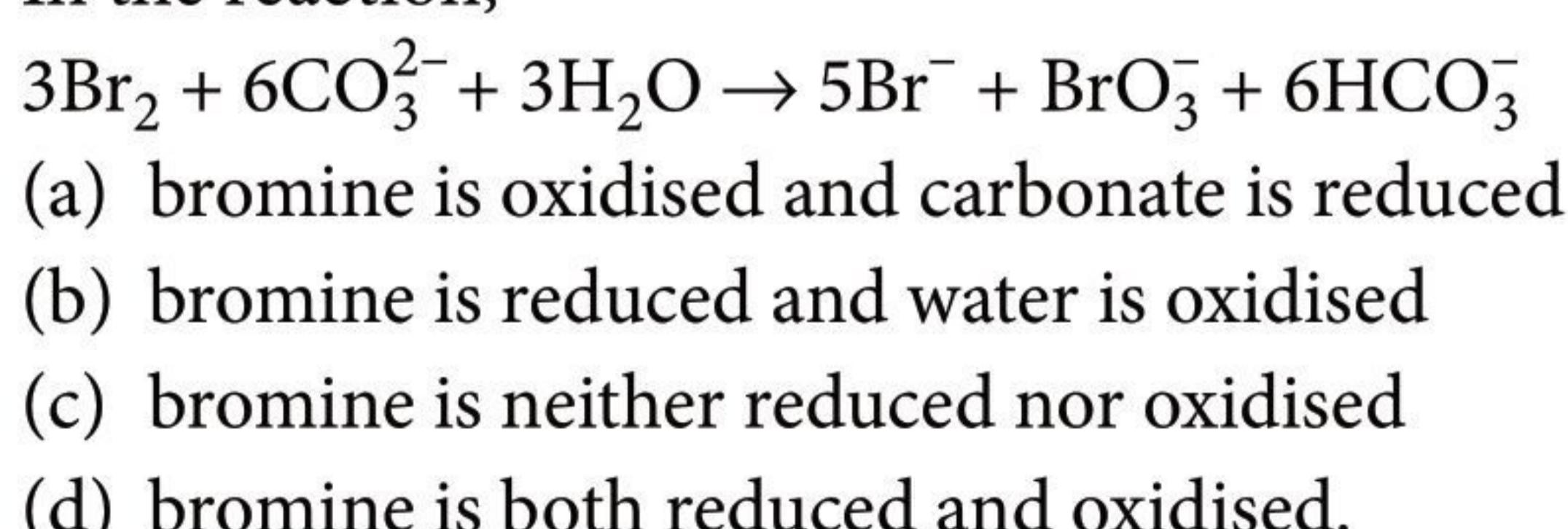
4. The equilibrium constant for the reaction,



Equilibrium constant for the reaction,



5. In the reaction,



6. The equilibrium constant  $K_c$  value for a gaseous homogeneous equilibrium at  $227^\circ\text{C}$  is  $2.05 \times 10^{-5}$  mol  $\text{L}^{-1}$ . The  $K_p$  value in atmosphere for this equilibrium at same temperature is \_\_\_\_\_. ( $R = 8.2 \times 10^{-2} \text{ L atm K}^{-1} \text{ mol}^{-1}$ )  $\text{A}_{(g)} \rightleftharpoons 2\text{B}_{(g)}$

(a)  $5.0 \times 10^{-6}$  (b)  $8.405 \times 10^{-4}$   
 (c)  $5.0 \times 10^{-5}$  (d)  $8.405 \times 10^{-3}$

7. Chlorine in +1 oxidation state is in

(a)  $\text{HCl}$  (b)  $\text{HClO}_4$  (c)  $\text{ICl}$  (d)  $\text{Cl}_2\text{O}$

8. 28 g of  $\text{N}_2$  and 6 g of  $\text{H}_2$  were mixed. At equilibrium 17 g  $\text{NH}_3$  was produced. The weights of  $\text{N}_2$  and  $\text{H}_2$  at equilibrium are respectively

(a) 11 g, 0 g (b) 1 g, 3 g  
 (c) 14 g, 3 g (d) 11 g, 3 g

9. In the reaction,  $3\text{CuO} + 2\text{NH}_3 \rightarrow \text{N}_2 + 3\text{H}_2\text{O} + 3\text{Cu}$  the change of  $\text{NH}_3$  to  $\text{N}_2$  involves

(a) loss of 6 electrons per mol of  $\text{N}_2$   
 (b) loss of 3 electrons per mol of  $\text{N}_2$   
 (c) gain of 6 electrons per mol of  $\text{N}_2$   
 (d) gain of 3 electrons per mol of  $\text{N}_2$

10. Which one of the following conditions will favour maximum formation of the product in the reaction  $\text{A}_{2(g)} + \text{B}_{2(g)} \rightleftharpoons \text{X}_{2(g)}$ ,  $\Delta_rH = -X \text{ kJ}$ ?

(a) Low temperature and high pressure  
 (b) Low temperature and low pressure  
 (c) High temperature and high pressure  
 (d) High temperature and low pressure

11. Given that  $E^\circ_{\text{K}^+/\text{K}} = -2.93 \text{ V}$ ;  $E^\circ_{\text{Fe}^{2+}/\text{Fe}} = -0.44 \text{ V}$ ;  $E^\circ_{\text{Zn}^{2+}/\text{Zn}} = -0.76 \text{ V}$ ;  $E^\circ_{\text{Cu}^{2+}/\text{Cu}} = 0.34 \text{ V}$ . Based on this data, which of the following is the strongest reducing agent?

(a)  $\text{Cu}$  (b)  $\text{K}^+$  (c)  $\text{Zn}^{2+}$  (d)  $\text{Fe}$

12. The pH of a 0.05 M ammonia solution is 10.97. Find the ionization constant of the conjugate acid of ammonia,  $\text{NH}_4^+$ .

Given  $\text{p}K_w = 14.0$ ,  $K_b$  for ammonia =  $1.77 \times 10^{-5}$

(a)  $4.77 \times 10^{-5}$  (b)  $9.77 \times 10^{-5}$   
(c)  $4.99 \times 10^{-10}$  (d)  $5.64 \times 10^{-10}$

#### Assertion & Reason Type

**Directions :** In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :

(a) If both assertion and reason are true and reason is the correct explanation of assertion.  
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.  
(c) If assertion is true but reason is false.  
(d) If both assertion and reason are false.

13. **Assertion :** Reaction quotient is defined in the same way as equilibrium constant at any stage of the reaction.

**Reason :** If  $Q$  (reaction quotient)  $< K_c$  (equilibrium constant) reaction moves in direction of reactants.

14. **Assertion :** The equilibrium constant does not change on addition of catalyst.

**Reason :** A catalyst provides an alternative path of lower activation energy for conversion of reactants to products.

15. **Assertion :** The reactant which undergoes oxidation is called oxidant and the reactant which undergoes reduction is called reductant.

**Reason :** In a redox reaction, the oxidation number of oxidant decreases, while that of reductant increases.

#### JEE MAIN / JEE ADVANCED

#### Only One Option Correct Type

16. An example of a disproportionation reaction is

(a)  $2\text{KMnO}_4 \rightarrow \text{K}_2\text{MnO}_4 + \text{MnO}_2 + \text{O}_2$   
(b)  $2\text{NaBr} + \text{Cl}_2 \rightarrow 2\text{NaCl} + \text{Br}_2$   
(c)  $2\text{CuBr} \rightarrow \text{CuBr}_2 + \text{Cu}$   
(d)  $2\text{MnO}_4^- + 10\text{I}^- + 16\text{H}^+ \rightarrow 2\text{Mn}^{2+} + 5\text{I}_2 + 8\text{H}_2\text{O}$

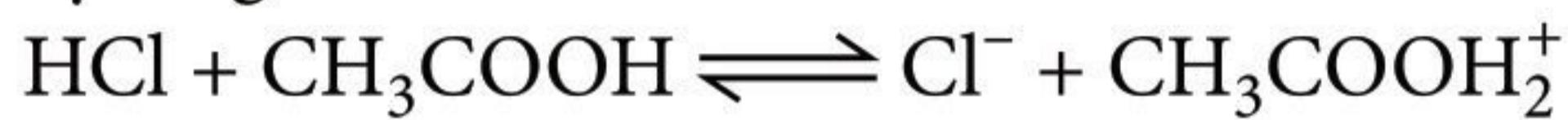
17. 0.1 mole of  $\text{CH}_3\text{NH}_2$  ( $K_b = 5 \times 10^{-4}$ ) is mixed with 0.08 mole of  $\text{HCl}$  and diluted to one litre. What will be the  $\text{H}^+$  concentration in the solution?

(a)  $8 \times 10^{-2} \text{ M}$  (b)  $8 \times 10^{-11} \text{ M}$   
(c)  $8 \times 10^{-15} \text{ M}$  (d)  $8 \times 10^{-5} \text{ M}$

18. In which of the following reactions, hydrogen peroxide acts as an oxidizing agent?

(a)  $\text{I}_2 + \text{H}_2\text{O}_2 + 2\text{OH}^- \rightarrow 2\text{I}^- + 2\text{H}_2\text{O} + \text{O}_2$   
(b)  $\text{PbS} + 4\text{H}_2\text{O}_2 \rightarrow \text{PbSO}_4 + 4\text{H}_2\text{O}$   
(c)  $2\text{MnO}_4^- + 3\text{H}_2\text{O}_2 \rightarrow 2\text{MnO}_2 + 3\text{O}_2 + 2\text{H}_2\text{O} + 2\text{OH}^-$   
(d)  $\text{HOCl} + \text{H}_2\text{O}_2 \rightarrow \text{H}_3\text{O}^+ + \text{Cl}^- + \text{O}_2$

19. The following equilibrium is established when hydrogen chloride is dissolved in acetic acid.



The set that characterises the conjugate acid-base pairs is :

(a)  $(\text{HCl}, \text{CH}_3\text{COOH})$  and  $(\text{CH}_3\text{COOH}_2^+, \text{Cl}^-)$   
(b)  $(\text{HCl}, \text{CH}_3\text{COOH}_2^+)$  and  $(\text{CH}_3\text{COOH}, \text{Cl}^-)$   
(c)  $(\text{CH}_3\text{COOH}_2^+, \text{HCl})$  and  $(\text{Cl}^-, \text{CH}_3\text{COOH})$   
(d)  $(\text{HCl}, \text{Cl}^-)$  and  $(\text{CH}_3\text{COOH}_2^+, \text{CH}_3\text{COOH})$

#### More than One Option Correct Type

20. For the gas phase reaction,



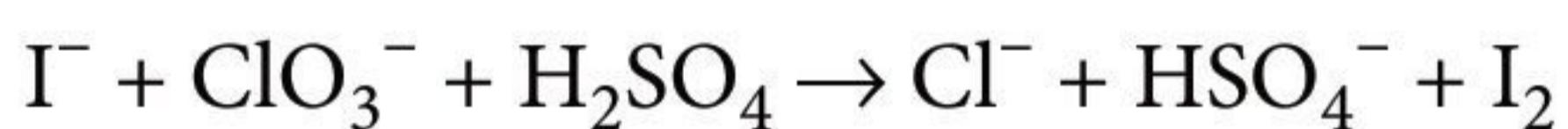
carried out in a vessel, the equilibrium concentration of  $\text{C}_2\text{H}_4$  can be increased by

(a) increasing the temperature  
(b) decreasing the pressure  
(c) removing some  $\text{H}_2$   
(d) adding some  $\text{C}_2\text{H}_6$

21.  $\text{Fe}^{3+}$  is reduced to  $\text{Fe}^{2+}$  by using

(a)  $\text{H}_2\text{O}_2$  in presence of  $\text{NaOH}$   
(b)  $\text{Na}_2\text{O}_2$  in water  
(c)  $\text{H}_2\text{O}_2$  in presence of  $\text{H}_2\text{SO}_4$   
(d)  $\text{Na}_2\text{O}_2$  in presence of  $\text{H}_2\text{SO}_4$

22. For the reaction :



The correct statement(s) in the balanced equation is/are

(a) stoichiometric coefficient of  $\text{HSO}_4^-$  is 6  
(b) iodide is oxidized  
(c) sulphur is reduced  
(d)  $\text{H}_2\text{O}$  is one of the products.

23. When  $\text{NaNO}_3$  is heated in a closed vessel, oxygen is liberated and  $\text{NaNO}_2$  is left behind. At equilibrium

(a) addition of  $\text{NaNO}_2$  favours reverse reaction  
(b) addition of  $\text{NaNO}_3$  favours forward reaction  
(c) increasing temperature favours forward reaction  
(d) increasing pressure favours reverse reaction.

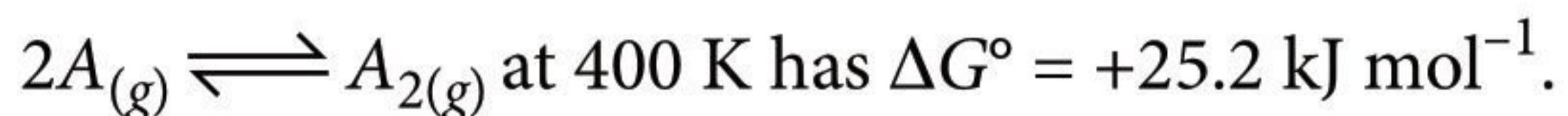
### Integer / Numerical Value Type

24. The solubility product of  $\text{PbI}_2$  is  $8.0 \times 10^{-9}$ . The solubility of lead iodide in 0.1 molar solution of lead nitrate is  $x \times 10^{-6}$  mol/L. The value of  $x$  is \_\_\_\_\_. (Rounded off to the nearest integer)

[Given  $\sqrt{2} = 1.41$ ]

25. The difference in the oxidation numbers of the two types of sulphur atoms in  $\text{Na}_2\text{S}_4\text{O}_6$  is \_\_\_\_\_.

26. The gas phase reaction



The equilibrium constant  $K_c$  for this reaction is \_\_\_\_\_  $\times 10^{-2}$ . (Round off to the Nearest Integer).

[Use :  $R = 8.3 \text{ J mol}^{-1} \text{ K}^{-1}$ ,  $\ln 10 = 2.3$

$\log_{10} 2 = 0.30$ , 1 atm = 1 bar]

[antilog (-0.3) = 0.501]

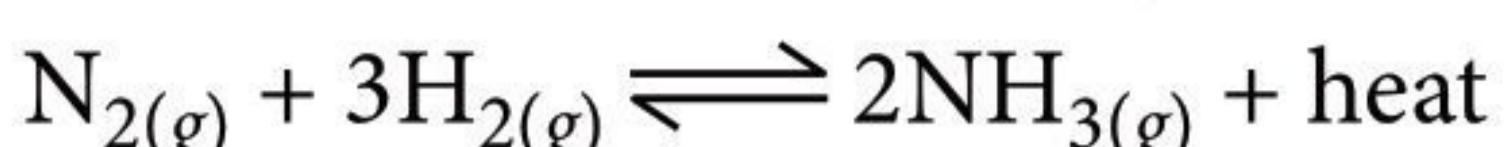
### Comprehension Type

Le Chatelier's principle is also known as the equilibrium law, used to predict the effect of change on a system at chemical equilibrium. This principle states that equilibrium adjusts the forward and backward reactions in such a way as to accept the change affecting the equilibrium condition. When factors like concentration, pressure, temperature, inert gas that affect equilibrium are changed, the equilibrium will shift in that direction where the effects that caused by these changes are nullified. This principle is also used to manipulate reversible reaction in order to obtain suitable outcomes.

27. In which one of the following equilibria will the point of equilibrium shift to left when the pressure of the system is increased?

(a)  $\text{H}_{2(g)} + \text{I}_{2(g)} \rightleftharpoons 2\text{HI}_{(g)}$   
(b)  $2\text{NH}_{3(g)} \rightleftharpoons \text{N}_{2(g)} + 3\text{H}_{2(g)}$   
(c)  $\text{C}_{(s)} + \text{O}_{2(g)} \rightleftharpoons \text{CO}_{2(g)}$   
(d)  $2\text{H}_{2(g)} + \text{O}_{2(g)} \rightleftharpoons 2\text{H}_2\text{O}_{(g)}$

28. For the reversible reaction,



The equilibrium shifts in forward direction

(a) by increasing the concentration of  $\text{NH}_{3(g)}$   
(b) by decreasing the pressure  
(c) by decreasing the concentrations of  $\text{N}_{2(g)}$  and  $\text{H}_{2(g)}$   
(d) by increasing pressure and decreasing temperature.

### Matrix Match Type

29. Match the column I with column II and mark the appropriate choice.

	Column I		Column II
A.	$\text{CH}_3\text{COONa}$	(i)	Almost neutral, pH > 7 or < 7
B.	$\text{NH}_4\text{Cl}$	(ii)	Acidic, pH < 7
C.	$\text{NaNO}_3$	(iii)	Alkaline, pH > 7
D.	$\text{CH}_3\text{COONH}_4$	(iv)	Neutral, pH = 7

(a) A  $\rightarrow$  (i), B  $\rightarrow$  (ii), C  $\rightarrow$  (iii), D  $\rightarrow$  (iv)

(b) A  $\rightarrow$  (ii), B  $\rightarrow$  (iii), C  $\rightarrow$  (iv), D  $\rightarrow$  (i)

(c) A  $\rightarrow$  (iii), B  $\rightarrow$  (ii), C  $\rightarrow$  (iv), D  $\rightarrow$  (i)

(d) A  $\rightarrow$  (iv), B  $\rightarrow$  (i), C  $\rightarrow$  (iii), D  $\rightarrow$  (ii)

30. Match the column I with column II and mark the appropriate choice.

	Column I (Compound)		Column II (Oxidation state of Fe)
A.	$\text{K}_3[\text{Fe}(\text{OH})_6]$	(i)	+8/3
B.	$\text{K}_2[\text{FeO}_4]$	(ii)	+2
C.	$\text{FeSO}_4 \cdot (\text{NH}_4)_2\text{SO}_4 \cdot 6\text{H}_2\text{O}$	(iii)	+3
D.	$\text{Fe}_3\text{O}_4$	(iv)	+6

(a) A  $\rightarrow$  (iii), B  $\rightarrow$  (i), C  $\rightarrow$  (ii), D  $\rightarrow$  (iv)

(b) A  $\rightarrow$  (iii), B  $\rightarrow$  (iv), C  $\rightarrow$  (ii), D  $\rightarrow$  (i)

(c) A  $\rightarrow$  (i), B  $\rightarrow$  (iii), C  $\rightarrow$  (ii), D  $\rightarrow$  (iv)

(d) A  $\rightarrow$  (iv), B  $\rightarrow$  (ii), C  $\rightarrow$  (i), D  $\rightarrow$  (iii)



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CLASS-XII

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## Unit 2

## Electrochemistry | Chemical Kinetics

### ELECTROCHEMISTRY

Electrochemistry is the study of production of electricity from energy released during spontaneous chemical reactions and the use of electrical energy to bring about non-spontaneous chemical transformations.

### ELECTROCHEMICAL CELLS

- The device which converts the chemical energy liberated during the chemical reaction to electrical energy is called electrochemical cell. The electrochemical cells are also called **galvanic** or **voltaic cells** e.g., Daniell cell.
- **Electrolytic cell** : It is a device which converts electrical energy into chemical energy.

#### Differences between Electrochemical cell and Electrolytic cell

S. No.	Electrochemical cell (Galvanic or Voltaic cell)	Electrolytic cell
1.	It is a device which converts chemical energy into electrical energy.	It is a device which converts electrical energy into chemical energy.
2.	It is based upon the redox reaction which is spontaneous. <i>i.e.</i> , $\Delta G = -ve$	The redox reaction is non-spontaneous and takes place only when electrical energy is supplied. <i>i.e.</i> , $\Delta G = +ve$
3.	Two electrodes are usually set up in two separate beakers.	Both the electrodes are suspended in the solution or molten electrolyte in the same beaker.
4.	The electrolytes taken in the two beakers are different.	Only one electrolyte is taken.
5.	The electrodes taken are of different materials.	The electrodes taken may be of the same or different materials.
6.	The electrode on which oxidation takes place is called the <b>anode</b> (or <i>-ve</i> pole) and the electrode on which reduction takes place is called the <b>cathode</b> (or <i>+ve</i> pole).	The electrode which is connected to the <i>-ve</i> terminal of the battery is called the <b>cathode</b> ; the cations migrate to it which gain electrons and hence, a reduction takes place, the other electrode is called the <b>anode</b> .
7.	To set up this cell, a salt bridge/porous pot is used.	No salt bridge is used in this case.

- In Galvanic cells, the Gibbs energy of the spontaneous redox reaction is converted into electrical work which may be used for running a motor or other electrical gadgets like heater, fan, geyser, etc.
- An electrochemical cell consists of two compartments known as **half cells**. A half cell consists of a metallic rod *i.e.*, electrode dipped into solution of its salt called **electrolyte**.
- The two half cells are connected by a metallic wire through a voltameter and a key, and electrolyte of the two half cells, are connected internally through a **salt bridge**. Salt bridge completes the electrical

circuit and maintains the electrical neutrality of electrolytes.

- **Representation of a Galvanic cell :**

- The interface across which a potential difference exists is shown by single vertical line. e.g.,  $\text{Zn} | \text{Zn}^{2+}$  or  $\text{Cu}^{2+} | \text{Cu}$
- When the two solutions are separated by salt bridge, then it is indicated by double vertical line (||), e.g.,  $\text{Cu}^{2+} || \text{Zn}^{2+}$
- The oxidation half cell is always written on the left hand side and *vice-versa*. e.g.  $\text{Zn} | \text{Zn}^{2+} || \text{Cu}^{2+} | \text{Cu}$
- The concentration of the solution, pressure of gases and physical states involved are also indicated in the cell information as :  $\text{Pt, H}_2(0.9 \text{ atm}) | \text{H}^+(a=0.1) || \text{Cu}^{2+}(a=0.1) | \text{Cu}$

## EMF

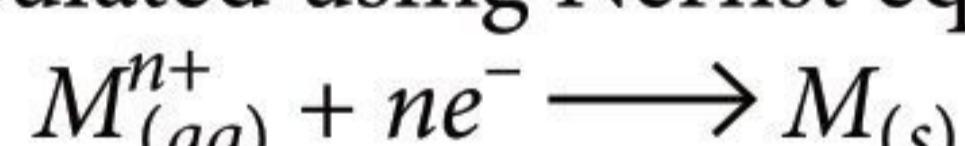
- The electrode potential difference between the two half-cells is known as electromotive force (EMF) of the cell or cell potential or cell voltage.
- $E_{\text{cell}}^{\circ} = E_{\text{ox}}^{\circ}(\text{anode}) + E_{\text{red}}^{\circ}(\text{cathode})$   
 $E_{\text{cell}}^{\circ} = E_{\text{red}}^{\circ}(\text{cathode}) - E_{\text{red}}^{\circ}(\text{anode}) = E_{\text{right}}^{\circ} - E_{\text{left}}^{\circ}$   
 $E_{\text{cell}}^{\circ} = E_{\text{ox}}^{\circ}(\text{anode}) - E_{\text{ox}}^{\circ}(\text{cathode})$

## ELECTROCHEMICAL SERIES

- When various electrodes are arranged in order of increasing or decreasing values of their standard reduction potentials we get a series called **electrochemical series**.

## NERNST EQUATION

- This equation relates the e.m.f. of a cell to the concentrations of reactants and products under a given set of conditions.
- For a general reaction with different concentrations the actual value of reduction potential can be calculated using Nernst equation.



Nernst equation is written as :

$$E_{(M^{n+}/M)} = E_{(M^{n+}/M)}^{\circ} - \frac{RT}{nF} \ln \frac{[M]}{[M^{n+}]}$$

$$\text{or } E_{(M^{n+}/M)} = E_{(M^{n+}/M)}^{\circ} - \frac{2.303RT}{nF} \log \frac{[M]}{[M^{n+}]}$$

where,  $E$  = Reduction potential of electrode

$E^{\circ}$  = Standard reduction potential of electrode

$R$  = Gas constant ( $8.314 \text{ J K}^{-1} \text{ mol}^{-1}$ )

$T$  = Kelvin temperature

$F$  = Faraday, equal to 96500 coulombs

Since concentrations of pure solids and liquids are taken as unity, then

$$E = E^{\circ} + \frac{2.303RT}{nF} \log [M^{n+}] \quad \dots(i)$$

On substituting the values, equation (i) becomes

$$E = E^{\circ} + \frac{0.0591}{n} \log [M^{n+}]$$

- This equation can be used to calculate electrode potential of an electrode having a concentration other than 1 M.
- Nernst equation is also used to calculate the EMF of a cell having known concentration of ions and also standard EMF.
- **Equilibrium constant from Nernst equation :** At equilibrium,  $E_{\text{cell}} = 0 \therefore E_{\text{cell}}^{\circ} = \frac{2.303RT}{nF} \log K_c$
- **Electrochemical cell and Gibbs energy of the reaction :** Reversible workdone by galvanic cell is equal to decrease in its Gibbs energy and therefore given as,  $\Delta_r G = -nFE_{\text{cell}}^{\circ}$  or  $\Delta_r G^{\circ} = -nFE_{\text{cell}}^{\circ}$  or  $\Delta_r G^{\circ} = -RT \ln K = -2.303RT \log K$

## CONDUCTANCE OF ELECTROLYTIC SOLUTIONS

### Electrolytic Conductance

- The property of facilitating the flow of electricity through conductor, is known as the conductance of the conductor. Mathematically;  
 $\text{Conductance} = 1/\text{Resistance}; C = 1/R \text{ ohm}^{-1}$   
The SI units of conductance is Siemens (S).

### Specific Conductance

- The resistance of any conductor is  $R \propto l$ ;  $l$  = length  
 $R \propto 1/a$ ;  $a$  = cross-sectional area  
 $R = \rho l/a$ ;  $\rho$  = specific resistance  
The reciprocal of specific resistance is known as specific conductance or conductivity.
- Specific conductance =  $\frac{1}{\text{Specific resistance}}$   
 $\kappa = \frac{1}{\rho} = \frac{l}{R \cdot a} = \frac{l}{a} \times C \text{ ohm}^{-1} \text{ cm}^{-1}$ ;  $\frac{l}{a}$  = cell constant

### Molar Conductance

- "Molar conductance" ( $\Lambda_m$ ) or molar conductivity is defined as the conducting power of all the ions produced by one mole of the electrolyte in solution.  
 $\therefore \Lambda_m = \kappa \times V_m$ ; where  $V_m$  = volume of solution containing 1 mole of electrolyte.

If  $C_m$  is concentration in moles litre $^{-1}$  then,

$$\Lambda_m = \kappa \times \frac{1000}{C_m}; C_m = \text{molarity}$$

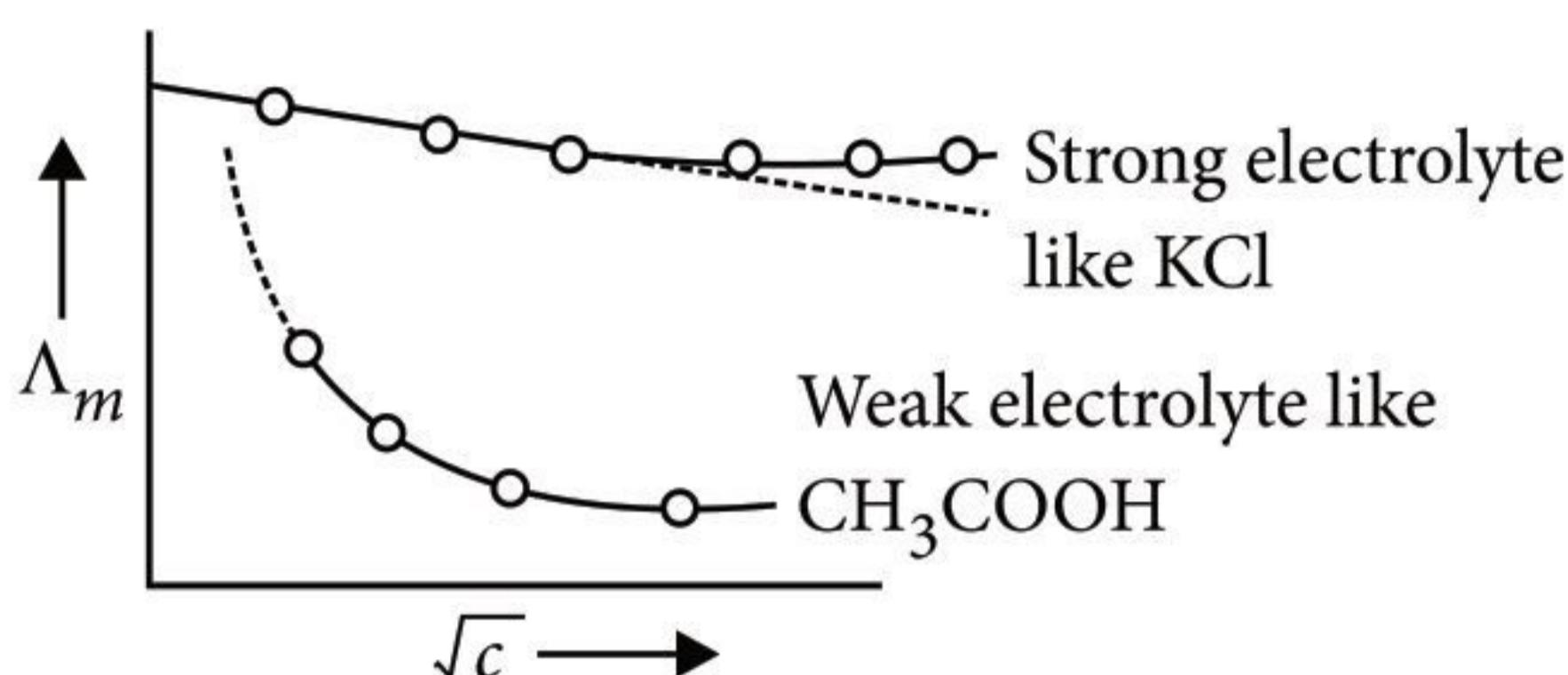
Unit of  $\Lambda_m$  is  $\text{ohm}^{-1} \text{cm}^2 \text{mol}^{-1}$ , in SI system it is  $\text{ohm}^{-1} \text{m}^2 \text{mol}^{-1}$  or  $\text{S m}^2 \text{mol}^{-1}$ .

If  $Z$  is total positive or negative charge per formula unit of electrolyte then,  $\Lambda_m = Z \times \Lambda_{eq}$

- **Variation of molar conductivity with concentration :**

- **For a strong electrolyte :** It is shown by Debye—Huckel Onsager equation as follows :

$$\Lambda_m = \Lambda_m^\infty - b\sqrt{c}$$



Here,  $\Lambda_m^\infty$  = Molar conductivity at infinite dilution (Limiting molar conductance)

$\Lambda_m$  = Molar conductivity at  $V$ -dilution

$b$  = Constant which depends upon the type of electrolyte ;  $c$  = Concentration

There is only a small increase in conductance with dilution.

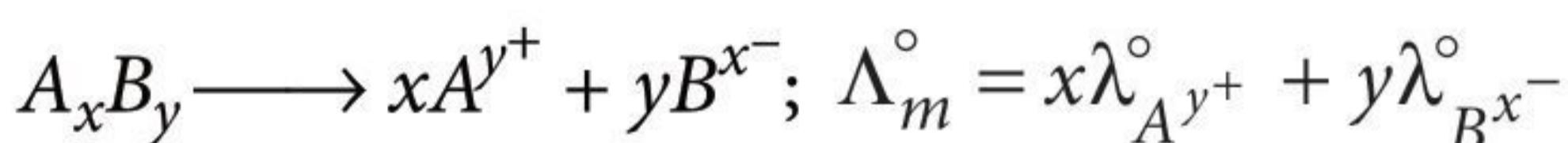
- **For a weak electrolyte :** Weak electrolyte dissociates to a much lesser extent, thus it has lower conductance as compared to strong electrolyte at the same temperature. There is a very large increase in conductance with dilution especially near to infinite dilution.

## KOHLRAUSCH'S LAW

- The limiting molar conductivity of an electrolyte is the sum of the limiting ionic conductivities of the cation and the anion each multiplied with the number of ions present in one formula unit of the electrolyte.

$$\Lambda_m^\circ = \lambda_+^\circ + \lambda_-^\circ$$

$\lambda_+^\circ$  and  $\lambda_-^\circ$  are called ionic conductivities of cation and anion at infinite dilution respectively.



- **Application of Kohlrausch's law :**

- Calculation of molar conductivity of weak electrolytes at infinite dilution.

$$\Lambda_m^\circ (\text{CH}_3\text{COOH}) = \lambda_{\text{CH}_3\text{COO}^-}^\circ + \lambda_{\text{H}^+}^\circ$$

- The above equation can be obtained as

$$\begin{aligned} \Lambda_m^\circ (\text{CH}_3\text{COOH}) &= \Lambda_m^\circ (\text{CH}_3\text{COONa}) + \Lambda_m^\circ (\text{HCl}) \\ &\quad - \Lambda_m^\circ (\text{NaCl}) \\ &= \lambda_{\text{CH}_3\text{COO}^-}^\circ + \lambda_{\text{Na}^+}^\circ + \lambda_{\text{H}^+}^\circ + \lambda_{\text{Cl}^-}^\circ - \lambda_{\text{Na}^+}^\circ - \lambda_{\text{Cl}^-}^\circ \end{aligned}$$

- Calculation of degree of dissociation :

$$\text{Degree of dissociation } (\alpha) = \Lambda_m^\circ / \Lambda_m^\infty$$

- Calculation of dissociation constant of a weak electrolyte :

$$\text{Dissociation constant } (K_c) = C\alpha^2 / 1 - \alpha$$

- Calculation of solubility of a sparingly soluble salt  
Solutions are considered saturated at infinite dilution so,  $\Lambda_m = \Lambda_m^\circ$  and molarity = solubility.

$$\text{Thus, } \Lambda_m^\circ = \frac{\kappa \times 1000}{\text{molarity}}$$

$$\text{or Solubility (mol L}^{-1}\text{)} = \frac{\kappa \times 1000}{\Lambda_m^\circ}$$

## Electrolysis

- **Electrolysis** is the process of decomposition of an electrolyte by passing electricity through its aqueous solution or molten state.

- **Faraday's first law of electrolysis :** The amount of chemical reaction which occurs at any electrode during electrolysis by a current is proportional to the quantity of electricity passed through the electrolyte (solution or melt).

- $W \propto Q$  or  $W = ZQ = Z \times I \times t$  where,  $Z$  is electrochemical equivalent of the substance deposited and  $Z = \frac{\text{Eq. wt. of substance}}{96500}$

- **Faraday's second law of electrolysis :** The amounts of different substances liberated by the same quantity of electricity passing through the electrolytic solution are proportional to their chemical equivalent weights.

$$\frac{W_1}{W_2} = \frac{E_1}{E_2} \text{ where } E \text{ is the equivalent weight}$$

$$= \frac{\text{Atomic mass of element}}{\text{No. of electrons gained or lost by one atom / ion of the element}}$$

## Some Commercial Cells (Batteries)

- Two or more galvanic cells connected in series are called *battery*.
- **Primary cells :** In the primary batteries, the reaction occurs only once and after use over a period of time, battery becomes dead and cannot be used again. e.g., mercury cell, dry cell.
- **Secondary cells :** These cells involve those redox reactions that converts chemical energy into electrical energy and can be reversed by passage of current. e.g., lead storage battery, nickel-cadmium storage cell.

- **Fuel cells** : Energy released from combustion of fuels is converted into electrical energy.

## CORROSION

- **Corrosion** : The slow eating away of metals when exposed to the atmosphere is called corrosion.
- **Corrosion of iron (Rusting)** : It is an electrochemical phenomenon which occurs in the presence of moisture and oxygen.
- **Methods used for prevention of corrosion** are barrier protection, sacrificial protection, anti-rust solutions.

## CHEMICAL KINETICS

### INTRODUCTION

- **Chemical kinetics** is the branch of chemistry which deals with the study of reaction rates and their mechanisms.
- Kinetic studies not only help to determine the speed or rate of a chemical reaction but also describe the conditions by which the reaction rates can be altered.

### Rate of a Chemical Reaction

- **Rate of reaction** is the change in concentration of any one of the reactants or products per unit time.
- For a hypothetical reaction,  $A \rightarrow B$

$$\text{Rate of reaction} = -\frac{\Delta[A]}{\Delta t} = \frac{\Delta[B]}{\Delta t}$$

Negative sign is used while expressing the rate in terms of reactants to show that concentration of

reactants is decreasing with time.

$$\text{Average rate of reaction} = -\frac{\Delta[A]}{\Delta t} \text{ or } \frac{\Delta[B]}{\Delta t}$$

$$\text{Instantaneous rate} = -\frac{d[A]}{dt} = \frac{d[B]}{dt}$$

$$\text{Unit of rate of reaction} = \text{mol L}^{-1}\text{s}^{-1}$$

### Factors Affecting Rate of Reaction

Factors	Effect on Reaction Rate
Increase in concentration	Increases
Increase in temperature	Increases
Presence of catalyst	Increases
Physical state	Rate is maximum in gaseous state
Decrease in size of reactant	Increases

### Rate Law and Rate Constant

- The rate constant depends only upon temperature.
- Units of  $k = (\text{mol})^{1-n} \text{ L}^{n-1} \text{s}^{-1}$ , where  $n$  = order of reaction
- The equation that correlates the rate of reaction with concentration of reactants is known as *rate law*.
- For a simple reaction,  $A + B \rightarrow C + D$   
 $\text{Rate} = k[A]^x[B]^y$  where  $k$  is the *rate constant* which is equal to the rate of reaction when concentration of each of the reactant is unity,  $x$  and  $y$  represent the order w.r.t.  $A$  and  $B$ .

### Differences between Order and Molecularity of a Reaction

Molecularity	Order
It is the number of molecules of reactants taking part in elementary step of a reaction.	It is the sum of powers to which concentration terms are raised in the rate law expression.
Molecularity is a theoretical value and is derived from mechanism proposed by using stoichiometric coefficients.	Order of reaction is an experimental value, derived from rate expression.
Molecularity can never be zero or fractional.	Order of reaction can be zero or fractional.
It is assigned for each step separately.	It is assigned for overall reaction.
It is independent of pressure and temperature.	It depends upon pressure and temperature.

### Half Life of a Reaction

- The time in which the concentration of a reactant is reduced to half of its initial concentration is called

half life of the reaction.

$$t_{1/2} \propto \frac{1}{a^{n-1}} \text{ where } n \text{ is the order of the reaction.}$$

## RATE LAW, INTEGRATED RATE LAW, HALF LIFE, UNIT OF RATE CONSTANT AND GRAPH FOR THE REACTIONS OF DIFFERENT ORDERS

Order	Rate Law	Integrated Rate Law	Half-life	Unit of Rate Constant	Graph
0	Rate = $k[A]^0$	$[A]_t = -kt + [A]_0$	$t_{1/2} = [A]_0/2k$	$\text{mol L}^{-1} \text{ s}^{-1}$	$[A] \text{ vs } t$ ; slope = $-k$
1	Rate = $k[A]^1$	$\ln[A]_t = -kt + \ln[A]_0$	$t_{1/2} = 0.693/k$	$\text{s}^{-1}$	$\ln[A] \text{ vs } t$ ; slope = $-k$
2	Rate = $k[A]^2$	$1/[A]_t = kt + 1/[A]_0$	$t_{1/2} = 1/k [A]_0$	$\text{L mol}^{-1} \text{ s}^{-1}$	$1/[A] \text{ vs } t$ ; slope = $k$
2	Rate = $k[A][B]$	$kt = \frac{1}{[A]_0 - [B]_0} \ln \frac{[B]_0[A]}{[A]_0[B]}$	—	$\text{L mol}^{-1} \text{ s}^{-1}$	—
$n$	Rate = $k[A]^n$	$(n-1)kt = \frac{1}{[A]^{n-1}} - \frac{1}{[A_0]^{n-1}}$	$t_{1/2} = \frac{2^{n-1} - 1}{k(n-1)[A]_0^{n-1}}$	$(\text{mol L}^{-1})^{1-n} \text{ s}^{-1}$	$\frac{1}{[A]^{n-1}} \text{ vs } t$ ; slope = $k$

### PSEUDOUNIMOLECULAR REACTIONS



According to law of mass action, this reaction should be bimolecular, but as water is present in excess its concentration remains practically constant. So, it does not effect the rate of reaction. Hence reactions showing such a behaviour are called pseudounimolecular reactions and they are also known as *pseudo first order reactions*.

### ARRHENIUS EQUATION

Arrhenius proposed a quantitative relationship between rate constant and temperature as  $k = Ae^{-E_a/RT}$   
 $k$  = rate constant,  $A$  = pre-exponential factor (called frequency factor),

$E_a$  = activation energy,  $T$  = temperature

Pre-exponential factor ( $A$ ) is a constant specific to a particular reaction. This factor is related to number of binary molecular collision per second per litre.

### Calculation of Activation Energy

The minimum energy that the reacting molecule must possess before undergoing a reaction is called activation energy.

$k = Ae^{-E_a/RT}$  (Arrhenius equation)

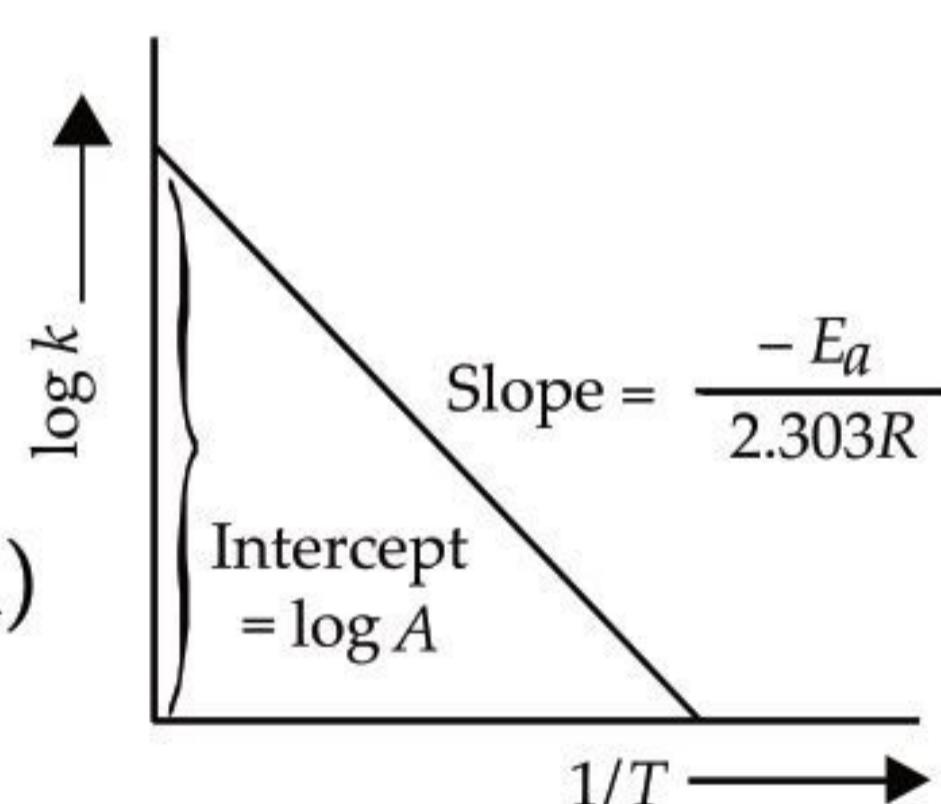
$$2.303 \log k = 2.303 \log A - \frac{E_a}{RT}$$

$$\log k = \log A - \frac{E_a}{2.303R} \left( \frac{1}{T} \right)$$

When  $\log k$  is plotted against  $1/T$ ,

$$\text{slope} = -\frac{E_a}{2.303R}$$

$$E_a = -2.303R \times \text{slope}$$



Alternatively, let  $k_1$  and  $k_2$  be the rate constants for the reaction at two different temperatures  $T_1$  and  $T_2$  respectively.

$$\log k_1 = \log A - \frac{E_a}{2.303RT_1}; \log k_2 = \log A - \frac{E_a}{2.303RT_2}$$

$$\log \frac{k_2}{k_1} = \frac{E_a}{2.303R} \left[ \frac{1}{T_1} - \frac{1}{T_2} \right]$$

By solving this, one can calculate activation energy.

- **Catalyst** : A positive catalyst increases the reaction rate by changing the path of reaction and lowering the activation energy.  
 Catalyst does not change Gibb's free energy, enthalpy of reaction and equilibrium constant.

### COLLISION THEORY OF CHEMICAL REACTIONS

- This theory is based on assumption that collisions between reactant molecules are responsible for the formation of product molecules, and rate of reaction is governed by the collision frequency ( $Z$ ), ( $Z$  = no. of collisions per second per unit volume of reaction mixture).
- Two factors decide whether a collision will be effective or not and these are :
  - **Energy factor** : For an effective collision, the colliding molecules must possess a certain minimum (or more) value of energy and this minimum value of energy is called threshold energy.
  - **Orientation factor** : Only those collisions among active molecules are effective which are properly oriented.  $k = P \cdot Z \cdot e^{-E_a/RT}$   
 where,  $P$  = orientation factor or probability factor.  
 $Z$  = collision frequency between molecules.



# WRAP it up!

## MCQs TYPE QUESTIONS

1. Rate constant in case of first order reaction is
  - (a) inversely proportional to the concentration units
  - (b) independent of concentration units
  - (c) directly proportional to concentration units
  - (d) inversely proportional to the square of concentration units.
2. Which of the following statements for order of reaction is not correct?
  - (a) Order can be determined experimentally.
  - (b) Order of reaction is equal to the sum of powers of concentration terms in rate law expression.
  - (c) Order cannot be fractional.
  - (d) Order is not affected by stoichiometric coefficient of the reactants.
3. The half-life of the reaction  $X \rightarrow Y$ , following first order kinetics, when the initial concentration of  $X$  is  $0.01 \text{ mol L}^{-1}$  and initial rate is  $0.00352 \text{ mol L}^{-1} \text{ min}^{-1}$  will be
  - (a) 19.69 min.
  - (b) 1.969 min.
  - (c) 7.75 min.
  - (d) 77.5 min.
4.  $E^\circ$  values of three metals are listed below.  
 $\text{Zn}^{2+}_{(aq)} + 2e^- \rightarrow \text{Zn}_{(s)}; E^\circ = -0.76 \text{ V}$   
 $\text{Fe}^{2+}_{(aq)} + 2e^- \rightarrow 2\text{Fe}_{(s)}; E^\circ = -0.44 \text{ V}$   
 $\text{Sn}^{2+}_{(aq)} + 2e^- \rightarrow \text{Sn}_{(s)}; E^\circ = -0.14 \text{ V}$   
Which of the following statements are correct on the basis of the above information?
  - (i) Zinc will be corroded in preference to iron if zinc coating is broken on the surface.
  - (ii) If iron is coated with tin and the coating is broken on the surface then iron will be corroded.
  - (iii) Zinc is more reactive than iron but tin is less reactive than iron.
    - (a) (i) and (ii) only
    - (b) (ii) and (iii) only
    - (c) (i), (ii) and (iii)
    - (d) (i) and (iii) only
5. **Assertion :** Kohlrausch law helps to find the molar conductivity of weak electrolyte at infinite dilution.  
**Reason :** Molar conductivity of a weak electrolyte at infinite dilution cannot be determined experimentally.
6. Both assertion and reason are true and reason is the correct explanation of assertion.
7. Both assertion and reason are true but reason is not the correct explanation of assertion.
8. Assertion is true but reason is false.
9. Both assertion and reason are false.
10. When 9.65 ampere current was passed for 1.0 hour into nitrobenzene in acidic medium, the amount of *p*-aminophenol produced is
  - (a) 10.9 g
  - (b) 98.1 g
  - (c) 109.0 g
  - (d) 9.81 g
11. In the electrolysis of aqueous sodium chloride solution, which of the half cell reaction will occur at anode?
  - (a)  $\text{Cl}^-_{(aq)} \rightarrow \frac{1}{2} \text{Cl}_2 + e^-; E^\circ_{\text{cell}} = 1.36 \text{ volts}$
  - (b)  $2\text{H}_2\text{O}_{(l)} \rightarrow \text{O}_2 + 4\text{H}^+ + 4e^-; E^\circ_{\text{cell}} = 1.23 \text{ volts}$
  - (c)  $\text{Na}^+_{(aq)} + e^- \rightarrow \text{Na}_{(s)}; E^\circ = -2.71 \text{ volts}$
  - (d)  $\text{H}^+_{(aq)} + e^- \rightarrow \frac{1}{2} \text{H}_2; E^\circ_{\text{cell}} = 0.00 \text{ volts}$
12. The standard electrode potentials of Zn and Ni are respectively  $-0.76 \text{ V}$  and  $-0.25 \text{ V}$ . Then the standard emf of the spontaneous cell by coupling these under standard conditions is
  - (a)  $+1.01 \text{ V}$
  - (b)  $-0.51 \text{ V}$
  - (c)  $+0.82 \text{ V}$
  - (d)  $+0.51 \text{ V}$
13. Three Faradays electricity was passed through an aqueous solution of iron(II) bromide. The weight of iron metal (at. wt. = 56) deposited at the cathode (in g) is
  - (a) 56
  - (b) 84
  - (c) 112
  - (d) 168
14. In  $\text{H}_2-\text{O}_2$  fuel cell, the reaction occurring at cathode is
  - (a)  $\text{O}_{2(g)} + 2\text{H}_2\text{O}_{(l)} + 4e^- \rightarrow 4\text{OH}^-_{(aq)}$
  - (b)  $\text{H}^+_{(aq)} + \text{OH}^-_{(aq)} \rightarrow \text{H}_2\text{O}_{(l)}$
  - (c)  $2\text{H}_{2(g)} + \text{O}_{2(g)} \rightarrow 2\text{H}_2\text{O}_{(l)}$
  - (d)  $\text{H}^+_{(aq)} + e^- \rightarrow \frac{1}{2} \text{H}_{2(g)}$
15. **Assertion :** Rate of reaction increases with increase in temperature.

**Reason :** Number of effective collisions increases with increase in temperature.

- (a) Both assertion and reason are true and reason is the correct explanation of assertion.
- (b) Both assertion and reason are true but reason is not the correct explanation of assertion.
- (c) Assertion is true but reason is false.
- (d) Both assertion and reason are false.

**12.** For effective collisions, colliding molecules must have

- (a) minimum potential energy
- (b) sufficient kinetic energy
- (c) sufficient potential energy
- (d) maximum energy of activation.

**13.** Which reaction characteristics are changing by the addition of a catalyst to a reaction at constant temperature?

(i) Activation energy	(ii) Equilibrium constant
(iii) Reaction entropy	(iv) Reaction enthalpy
(a) Only (i)	(b) Only (iii)
(c) Only (i) and (ii)	(d) All of these

**14.** The half-life of a first order reaction is 10 minutes. If initial amount is 0.08 mol/L and concentration at some instant is 0.01 mol/L, then  $t$  is

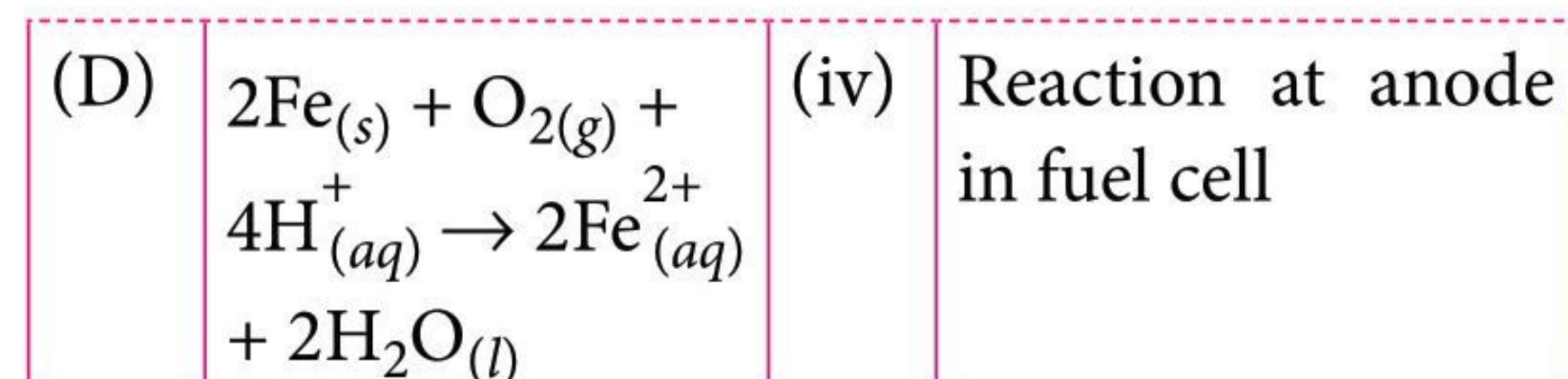
- (a) 10 minutes
- (b) 30 minutes
- (c) 20 minutes
- (d) 40 minutes.

**15.** The energies of activation for forward and reverse reactions for  $A_2 + B_2 \rightleftharpoons 2AB$  are 180 kJ mol<sup>-1</sup> and 200 kJ mol<sup>-1</sup> respectively. The presence of a catalyst lowers the activation energy of both (forward and reverse) reactions by 100 kJ mol<sup>-1</sup>. The magnitude of enthalpy change of the reaction ( $A_2 + B_2 \rightarrow 2AB$ ) in the presence of a catalyst will be (in kJ mol<sup>-1</sup>)

- (a) 20
- (b) 300
- (c) 120
- (d) 280

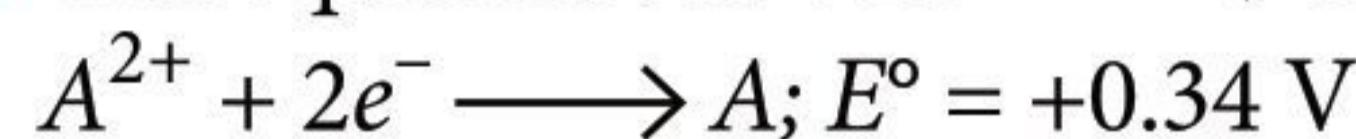
**16.** Match the column I with column II and mark the appropriate choice.

Column I		Column II	
(A)	$Pb_{(s)} + SO_{4(aq)}^{2-} \rightarrow PbSO_{4(s)} + 2e^-$	(i)	Rusting of iron
(B)	$2SO_{4(aq)}^{2-} \rightarrow S_2O_{8(aq)}^{2-} + 2e^-$	(ii)	Reaction at anode in a lead storage battery
(C)	$2H_{2(g)} + 4OH_{(aq)}^- \rightarrow 4H_2O_{(l)} + 4e^-$	(iii)	Electrolysis of concentrated $H_2SO_4$



- (a) (A)  $\rightarrow$  (i), (B)  $\rightarrow$  (ii), (C)  $\rightarrow$  (iii), (D)  $\rightarrow$  (iv)
- (b) (A)  $\rightarrow$  (ii), (B)  $\rightarrow$  (iii), (C)  $\rightarrow$  (iv), (D)  $\rightarrow$  (i)
- (c) (A)  $\rightarrow$  (iii), (B)  $\rightarrow$  (iv), (C)  $\rightarrow$  (i), (D)  $\rightarrow$  (ii)
- (d) (A)  $\rightarrow$  (iv), (B)  $\rightarrow$  (i), (C)  $\rightarrow$  (ii), (D)  $\rightarrow$  (iii)

**17.** Cell equation :  $A + 2B^+ \rightarrow A^{2+} + 2B$



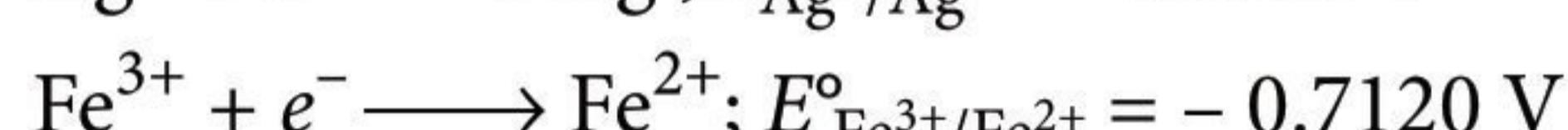
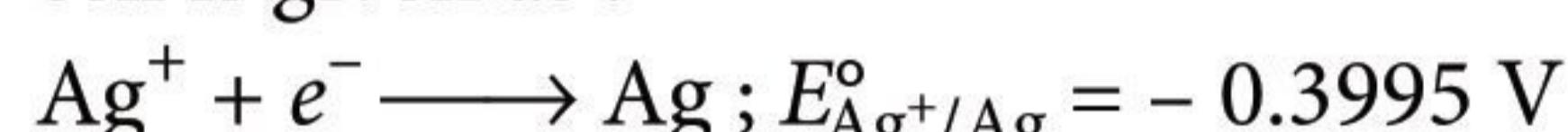
and  $\log_{10} K = 15.6$  at 300 K for cell reactions.

Find  $E^\circ$  for  $B^+ + e^- \rightarrow B$ .

$$\left[ \text{Given: } \frac{2.303 RT}{nF} = 0.059 \text{ at } 300 \text{ K} \right]$$

- (a) 0.80 V
- (b) 1.26 V
- (c) -0.54 V
- (d) +0.94 V

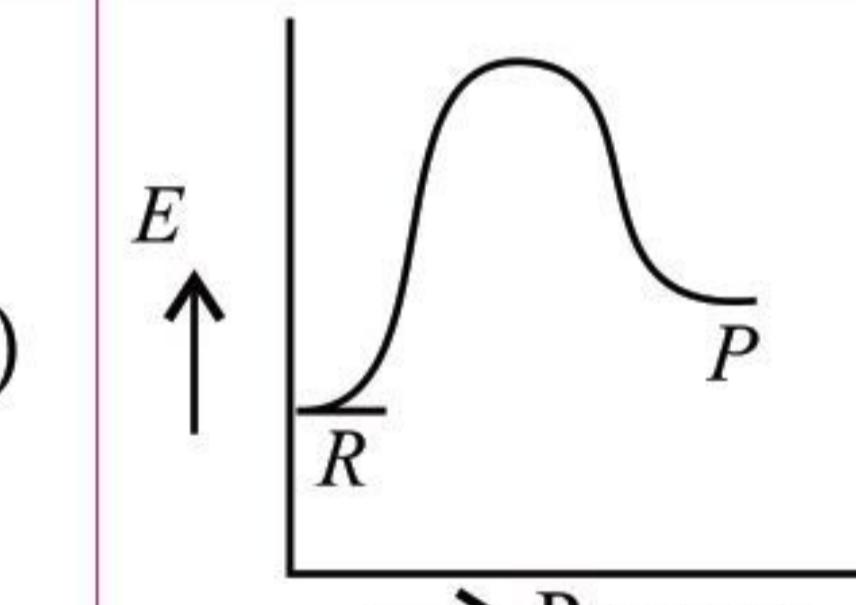
**18.** The two half-cell reactions of an electrochemical cell is given as :



The value of cell EMF will be

- (a) -0.3125 V
- (b) 0.3125 V
- (c) 1.114 V
- (d) -1.114 V

**19.** Match the column I with column II and mark the appropriate choice.

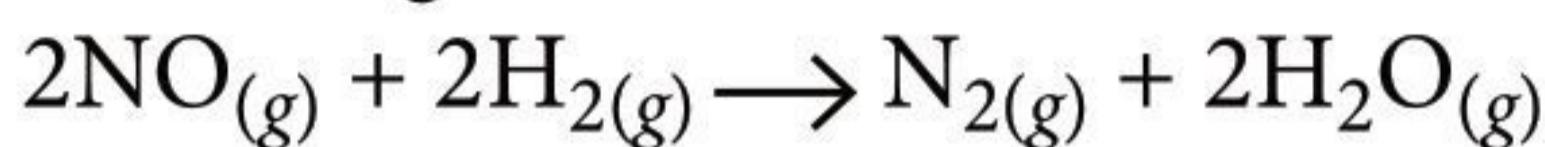
Column I		Column II	
(A)	Zero order	(i)	$\log \frac{k_2}{k_1} = \frac{E_a}{2.303R} \left[ \frac{T_2 - T_1}{T_1 T_2} \right]$
(B)	First order	(ii)	
(C)	Endothermic reaction	(iii)	$k = \frac{2.303}{t} \log \frac{[A]_0}{[A]}$
(D)	Activation energy	(iv)	$k = \frac{1}{t} ([A]_0 - [A])$

- (a) (A)  $\rightarrow$  (iv), (B)  $\rightarrow$  (iii), (C)  $\rightarrow$  (ii), (D)  $\rightarrow$  (i)
- (b) (A)  $\rightarrow$  (i), (B)  $\rightarrow$  (ii), (C)  $\rightarrow$  (iii), (D)  $\rightarrow$  (iv)
- (c) (A)  $\rightarrow$  (ii), (B)  $\rightarrow$  (iii), (C)  $\rightarrow$  (iv), (D)  $\rightarrow$  (i)
- (d) (A)  $\rightarrow$  (iii), (B)  $\rightarrow$  (iv), (C)  $\rightarrow$  (i), (D)  $\rightarrow$  (ii)

20. The rate constant of the reaction,  $2\text{N}_2\text{O}_5 \rightarrow 4\text{NO}_2 + \text{O}_2$  at 300 K is  $3 \times 10^{-5} \text{ s}^{-1}$ . If the rate of the reaction at the same temperature is  $2.4 \times 10^{-5} \text{ mol dm}^{-3} \text{ s}^{-1}$ , then the molar concentration of  $\text{N}_2\text{O}_5$  is  
 (a) 0.4 M (b) 0.8 M (c) 0.04 M (d) 0.08 M

### NUMERICAL VALUE TYPE QUESTIONS

21. The following data was obtained for chemical reaction given below at 975 K.



	[NO] mol L <sup>-1</sup>	[H <sub>2</sub> ] mol L <sup>-1</sup>	Rate mol L <sup>-1</sup> s <sup>-1</sup>
(A)	$8 \times 10^{-5}$	$8 \times 10^{-5}$	$7 \times 10^{-9}$
(B)	$24 \times 10^{-5}$	$8 \times 10^{-5}$	$2.1 \times 10^{-8}$
(C)	$24 \times 10^{-5}$	$32 \times 10^{-5}$	$8.4 \times 10^{-8}$

The order of the reaction with respect to NO is \_\_\_\_.

22. An oxidation-reduction reaction in which 3 electrons are transferred has a  $\Delta G^\circ$  of  $17.37 \text{ kJ mol}^{-1}$  at  $25^\circ\text{C}$ . The value of  $E_{\text{cell}}^\circ$  (in V) is \_\_\_\_  $\times 10^{-2}$ . ( $1 \text{ F} = 96,500 \text{ C mol}^{-1}$ )

23. For a first order reaction, the ratio of the time for 75% completion of a reaction to the time for 50% completion is \_\_\_\_\_. (Integer answer)

24. For an electrochemical cell,  $\text{Sn}_{(s)}|\text{Sn}^{2+} \text{ (aq, 1 M)}||\text{Pb}^{2+} \text{ (aq, 1 M)}|\text{Pb}_{(s)}$  the ratio  $\frac{[\text{Sn}^{2+}]}{[\text{Pb}^{2+}]}$  when this cell attains equilibrium is \_\_\_\_\_.  
 Given:  $E_{\text{Sn}^{2+}/\text{Sn}}^\circ = -0.14 \text{ V}$ ,  $E_{\text{Pb}^{2+}/\text{Pb}}^\circ = -0.13 \text{ V}$ ,  $\frac{2.303 \text{ RT}}{F} = 0.06$

25. The first order rate constant for the decomposition of  $\text{CaCO}_3$  at 700 K is  $6.36 \times 10^{-3} \text{ s}^{-1}$  and activation energy is  $209 \text{ kJ mol}^{-1}$ . Its rate constant (in  $\text{s}^{-1}$ ) at 600 K is  $x \times 10^{-6}$ . The value of  $x$  is \_\_\_\_\_. (Nearest integer)

[Given  $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$ ;  $\log 6.36 \times 10^{-3} = -2.19$ ,  $10^{-4.79} = 1.62 \times 10^{-5}$ ]

### SOLUTIONS

1. (b) 2. (c)

3. (b):  $\frac{dx}{dt} = k[X]$  (For a first order reaction)  
 $0.00352 = k \times 0.01 \Rightarrow k = 0.352 \text{ min}^{-1}$

$$t_{1/2} = \frac{0.693}{k} = \frac{0.693}{0.352} = 1.969 \text{ min.}$$

4. (c) 5. (a) 6. (d) 7. (a)  
 8. (d): The cell is represented as:  $\text{Zn}|\text{Zn}^{2+}||\text{Ni}^{2+}|\text{Ni}$   
 $E_{\text{cell}}^\circ = E_{\text{cathode}}^\circ - E_{\text{anode}}^\circ$   
 $= -0.25 - (-0.76) = -0.25 + 0.76 = 0.51 \text{ V}$

9. (b):  $\text{Fe}^{2+} + 2e^- \rightarrow \text{Fe}$   
 2F charge will deposit 56 g of Fe  
 1 F charge will deposit  $56/2 \text{ g of Fe}$   
 3 F charge will deposit  $3 \times 56/2 \text{ g of Fe} = 84 \text{ g of Fe}$

10. (a) 11. (a) 12. (b)  
 13. (a): Catalyst speeds up the chemical reaction by lowering down the activation energy.

14. (b):  $k = \frac{0.693}{t_{1/2}} = \frac{0.693}{10}$   
 $t = \frac{2.303}{k} \log \frac{0.08}{0.01} = \frac{2.303 \times 10}{0.693} \times \log 8 = 30 \text{ minutes}$

15. (a):  $\Delta H_R = E_f - E_b = 180 - 200 = -20 \text{ kJ mol}^{-1}$

16. (b) 17. (a) 18. (b) 19. (a)

20. (b): Rate constant,  $k = 3 \times 10^{-5} \text{ s}^{-1}$   
 From the unit of  $k$  it is clear that the reaction is of first order.

$$\Rightarrow \text{Rate} = k[\text{N}_2\text{O}_5]$$

$$\Rightarrow [\text{N}_2\text{O}_5] = \frac{\text{Rate}}{k} = \frac{2.4 \times 10^{-5}}{3 \times 10^{-5}} \text{ mol dm}^{-3}$$

$$= 0.8 \text{ mol dm}^{-3}$$

21. (1)

22. (-6): As  $\Delta G^\circ = -nFE_{\text{cell}}^\circ$   
 $17.37 \times 10^3 = -3 \times 96500 \times E_{\text{cell}}^\circ$   
 $\therefore E_{\text{cell}}^\circ = -\frac{17.37 \times 10^3 \text{ J mol}^{-1}}{3 \times 96500 \text{ C mol}^{-1}} = -0.06 \text{ V}$   
 $= -6 \times 10^{-2} \text{ V}$

23. (2) 24. (2.13) 25. (16)



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# CBSE warm-up!

CLASS-XII

Chapterwise practice questions for CBSE Exams as per the latest pattern  
and reduced syllabus by CBSE for the academic session 2022-23.

Series-5

## Coordination Compounds

Time Allowed : 3 hours  
Maximum Marks : 70

### GENERAL INSTRUCTIONS

**General Instructions : Read the following instructions carefully.**

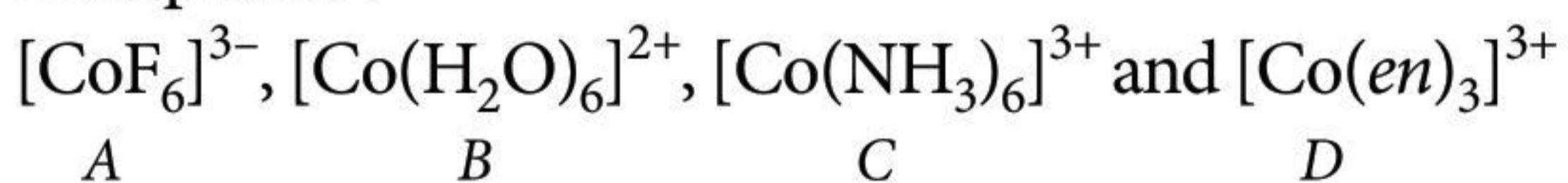
- (a) There are 35 questions in this question paper with internal choice.
- (b) SECTION A consists of 18 multiple-choice questions carrying 1 mark each.
- (c) SECTION B consists of 7 very short answer questions carrying 2 marks each.
- (d) SECTION C consists of 5 short answer questions carrying 3 marks each.
- (e) SECTION D consists of 2 case- based questions carrying 4 marks each.
- (f) SECTION E consists of 3 long answer questions carrying 5 marks each.
- (g) All questions are compulsory.
- (h) Use of log tables and calculators is not allowed

### SECTION A

**The following questions are multiple-choice questions with one correct answer. Each question carries 1 mark. There is no internal choice in this section.**

1. Arrange the following cobalt complexes in the order of increasing Crystal Field Stabilization Energy (CFSE) value.

Complexes :



A

B

C

D

Choose the correct option.

- (a)  $B < C < D < A$
- (b)  $B < A < C < D$
- (c)  $A < B < C < D$
- (d)  $C < D < B < A$

2. Which of the following complexes does not show geometrical isomerism?

- (a)  $[Pt(NH_3)_2Cl_2]$
- (b)  $[Co(NH_3)_4Cl_2]$
- (c)  $[CoCl_2(en)_2]$
- (d)  $[Ni(CO)_4]$

3. According to IUPAC system, what is the correct name of the compound  $[Cr(NH_3)_3(H_2O)_3]Cl_3$ ?

- (a) Triamminetriaquachromium(III) chloride

- (b) Triamminetriaquachromium chloride(III)
- (c) Tetraammoniumtriaquachromium(III) chloride
- (d) None of the above

4. EDTA can form complex with how many number of donor atoms?

- (a) One
- (b) Two
- (c) Six
- (d) Three

5.  $[Fe(NO_2)_3Cl_3]$  and  $[Fe(O - NO)_3Cl_3]$  shows

- (a) linkage isomerism
- (b) geometrical isomerism
- (c) optical isomerism
- (d) hydrate isomerism.

6. The complex ion which has no *d*-electrons in the central metal atom is

- (a)  $[MnO_4]^-$
- (b)  $[Co(NH_3)_6]^{3+}$
- (c)  $[Fe(CN)_6]^{3-}$
- (d)  $[Cr(H_2O)_6]^{3+}$

7. The coordination number of 'Co' in the complex  $[Co(en)_3]^{3+}$  is

- (a) 3
- (b) 6
- (c) 4
- (d) 5

8. Which of the following statements is/are correct?

- (i) In octahedral complexes,  $t_{2g}$  orbitals possess low energy as compared to  $e_g$  orbitals.

(ii) In tetrahedral complexes,  $t_{2g}$  orbitals possess high energy as compared to  $e_g$  orbitals.

(iii) In octahedral complexes,  $e_g$  orbitals possess low energy as compared to  $t_{2g}$  orbitals.

(a) (ii) only (b) (iii) only  
(c) (i) and (ii) (d) (i) and (iii)

9. Which of the following statements is correct about  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$  complex?

(a) Electronic configuration =  $3d^7 \rightarrow t_{2g}^5 e_g^2$ , no. of unpaired electrons = 3,  $\mu = 3.87$  B.M.  
(b) Electronic configuration =  $3d^6 \rightarrow t_{2g}^4 e_g^2$ , no. of unpaired electrons = 2,  $\mu = 2.87$  B.M.  
(c) Electronic configuration =  $3d^7 \rightarrow t_{2g}^6 e_g^1$ , no. of unpaired electrons = 1,  $\mu = 2.87$  B.M.  
(d) Electronic configuration =  $3d^7 = t_{2g}^3 e_g^4$ , no. of unpaired electrons = 3,  $\mu = 3.87$  B.M.

10. The spin only magnetic moment value of  $\text{Cr}(\text{CO})_6$  is

(a) 2.84 B.M. (b) 4.90 B.M.  
(c) 5.92 B.M. (d) 0 B.M.

11. The correct order for the wavelength of absorption in the visible region is

(a)  $[\text{Ni}(\text{NO}_2)_6]^{4-} < [\text{Ni}(\text{NH}_3)_6]^{2+} < [\text{Ni}(\text{H}_2\text{O})_6]^{2+}$   
(b)  $[\text{Ni}(\text{NO}_2)_6]^{4-} < [\text{Ni}(\text{H}_2\text{O})_6]^{2+} < [\text{Ni}(\text{NH}_3)_6]^{2+}$   
(c)  $[\text{Ni}(\text{H}_2\text{O})_6]^{2+} < [\text{Ni}(\text{NH}_3)_6]^{2+} < [\text{Ni}(\text{NO}_2)_6]^{4-}$   
(d)  $[\text{Ni}(\text{NH}_3)_6]^{2+} < [\text{Ni}(\text{H}_2\text{O})_6]^{2+} < [\text{Ni}(\text{NO}_2)_6]^{4-}$

12. In  $\text{Fe}(\text{CO})_5$ , the Fe – C bond possesses

(a)  $\pi$ -character only  
(b) both  $\sigma$  and  $\pi$  characters  
(c) ionic character  
(d)  $\sigma$ -character only.

13. Wilkinson's catalyst is used for

(a) epoxidation (b) hydrogenation  
(c) polymerisation (d) substitution.

14. Few isomers are given below. Mark the correct statement regarding them.

(i)  $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$   
(ii)  $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]\text{Cl}_2 \cdot \text{H}_2\text{O}$   
(iii)  $[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2]\text{Cl} \cdot 2\text{H}_2\text{O}$

(a) (i), (ii) and (iii) are hydrate isomers.  
(b) (i), (ii) and (iii) are coordination isomers.  
(c) (i), (ii) and (iii) are ionisation isomers.  
(d) (i) and (ii) are stereoisomers.

15. Given below are two statements labelled as Assertion (A) and Reason (R)

**Assertion :** Different metal ions have different colours with the same ligand.

**Reason :** Different metal ions have different crystal field splitting energy.

Select the most appropriate answer from the options given below:

(a) Both A and R are true and R is the correct explanation of A.  
(b) Both A and R are true but R is not the correct explanation of A.  
(c) A is true but R is false.  
(d) A is false but R is true.

16. Given below are two statements labelled as Assertion (A) and Reason (R)

**Assertion :**  $[\text{Cu}(\text{NH}_3)_4]^{2+}$  is coloured while  $[\text{Cu}(\text{CN})_4]^{3-}$  ion is colourless.

**Reason :**  $[\text{Cu}(\text{NH}_3)_4]^{2+}$  has  $sp^2d$  hybridisation.

Select the most appropriate answer from the options given below:

(a) Both A and R are true and R is the correct explanation of A.  
(b) Both A and R are true but R is not the correct explanation of A.  
(c) A is true but R is false.  
(d) A is false but R is true.

17. Given below are two statements labelled as Assertion (A) and Reason (R)

**Assertion :**  $[\text{Cr}(\text{NH}_3)_6]^{3+}$  is paramagnetic.

**Reason :**  $[\text{Cr}(\text{NH}_3)_6]^{3+}$  shows  $d^2sp^3$  hybridisation.

Select the most appropriate answer from the options given below:

(a) Both A and R are true and R is the correct explanation of A.  
(b) Both A and R are true but R is not the correct explanation of A.  
(c) A is true but R is false.  
(d) A is false but R is true.

18. Given below are two statements labelled as Assertion (A) and Reason (R)

**Assertion :**  $[\text{Ni}(\text{CN})_4]^{2-}$  has square planar and  $[\text{NiCl}_4]^{2-}$  has tetrahedral shape.

**Reason :**  $[\text{Ni}(\text{CN})_4]^{2-}$  is diamagnetic while  $[\text{NiCl}_4]^{2-}$  is paramagnetic.

Select the most appropriate answer from the options given below:

(a) Both A and R are true and R is the correct explanation of A.  
(b) Both A and R are true but R is not the correct explanation of A.  
(c) A is true but R is false.  
(d) A is false but R is true.

## SECTION B

**This section contains 7 questions with internal choice in two questions. The following questions are very short answer type and carry 2 marks each.**

19. Using IUPAC norms write the formulae for the following :

- Pentaamminenitrito-O-cobalt(III) chloride
- Potassium tetracyanidonickelate(II)

20. a. On the basis of crystal field theory, write the electronic configuration of  $d^4$  ion if  $\Delta_o < P$ .  
 b. Write the hybridization and magnetic behaviour of the complex  $[\text{Ni}(\text{CO})_4]$ . (At. no. of Ni = 28)

**OR**

Write the state of hybridization, the shape and the magnetic behaviour of the following complex entities :

a.  $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$     b.  $[\text{Co}(\text{en})_3]\text{Cl}_3$

21. Using Crystal Field Theory, write the electronic configuration of iron ion in the following complex ion. Also predict its magnetic behaviour :  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$

**OR**

a. Predict the geometry of  $[\text{Ni}(\text{CN})_4]^{2-}$   
 b. Calculate the spin only magnetic moment of  $[\text{Cu}(\text{NH}_3)_4]^{2+}$  ion.

22. Why is  $[\text{NiCl}_4]^{2-}$  paramagnetic while  $[\text{Ni}(\text{CN})_4]^{2-}$  is diamagnetic? (Atomic number of Ni = 28)

23. a. Write the IUPAC name of the following complex :  $\text{K}_2[\text{PdCl}_4]$   
 b. Using crystal field theory, write the electronic configuration of  $d^5$  ion, if  $\Delta_o > P$ .

24. Using IUPAC norms write the formulae for the following :

a. Sodium dicyanidoaurate(I)  
 b. Tetraamminechloridonitrito-N-platinum(IV) sulphate

25. Write IUPAC name of the complex  $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]^+$ . Draw structures of geometrical isomers for this complex.

**SECTION C**

This section contains 5 questions with internal choice in two questions. The following questions are short answer type and carry 3 marks each.

26. a. Calculate the spin only magnetic moment of the complex  $[\text{FeF}_6]^{3-}$ . (Atomic number of Fe = 26)  
 b. Write the IUPAC name of the given complex :  $[\text{Co}(\text{NH}_3)_5\text{Cl}]\text{Cl}_2$   
 c. Why is the complex  $[\text{Co}(\text{en})_3]^{3+}$  more stable than  $[\text{CoF}_6]^{3-}$ ?

27. On the basis of VBT, answer the following question for the given coordination compound  $[\text{V}(\text{H}_2\text{O})_6]^{3+}$

a. What type of hybridisation is involved?  
 b. Whether the given complex is inner orbital octahedral or outer orbital octahedral complex?  
 c. What is the magnetic behaviour of the complex ion?  
 d. Calculate the spin only magnetic moment for the complex ion.

**OR**

On the basis of VBT, answer the following questions for the given coordination compound  $[\text{Co}(\text{NCS})_4]^{2-}$ ,

a. What is the oxidation state of the central metal atom/ion?  
 b. What type of hybridisation is involved?  
 c. What is the geometry and magnetic behaviour of the complex?  
 d. Calculate spin only magnetic moment.

28. Indicate the types of isomerism exhibited by the following complexes :

a.  $[\text{Co}(\text{NH}_3)_5(\text{NO}_2)]^{2+}$   
 b.  $[\text{Co}(\text{en})_3]\text{Cl}_3$  (en = ethylene diamine)  
 c.  $[\text{Pt}(\text{NH}_3)_2\text{Cl}_2]$

29. For the complex  $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ , write the hybridization, magnetic character and spin of the complex. (At. number Fe = 26)

30. Give reasons for any 3 of the following observations:

a.  $[\text{Ni}(\text{CO})_4]$  has tetrahedral geometry but it is diamagnetic.  
 b.  $[\text{Mn}(\text{CN})_6]^{3-}$  has two unpaired electrons whereas  $[\text{MnCl}_6]^{3-}$  has four unpaired electrons.  
 c.  $[\text{Fe}(\text{CN})_6]^{3-}$  ion is  $d^2\text{sp}^3$  hybridised.  
 d.  $[\text{Co}(\text{NH}_3)_6]^{3+}$  is a diamagnetic complex ion.

**SECTION D**

The following questions are case-based questions. Each question has an internal choice and carries 4 (1+1+2) marks each. Read the passage carefully and answer the questions that follow.

31. To explain bonding in coordination compounds various theories were proposed. One of the important theory was valence bond theory. According to that, the central metal ion in the complex makes available a number of empty orbitals for the formation of coordination bonds with suitable ligands. The appropriate atomic orbitals of the metal hybridise to give a set of equivalent orbitals of definite geometry. The  $d$ -orbitals involved in the hybridisation may be either inner  $d$ -orbitals i.e.,  $(n-1)d$  or outer  $d$ -orbitals i.e.,  $nd$ . For example,  $\text{Co}^{3+}$  forms both inner orbital and outer orbital complexes, with ammonia it forms  $[\text{Co}(\text{NH}_3)_6]^{3+}$  and with fluorine it forms  $[\text{CoF}_6]^{3-}$  complex ion.

**Answer the following questions :**

a. Discuss the hybridisation and magnetic character of  $[\text{CoF}_6]^{3-}$  ion.  
 b. Write the hybridisation and magnetic character of  $[\text{Co}(\text{C}_2\text{O}_4)_3]^{3-}$ . (At. no. of Co = 27)  
 c. The magnetic moment of  $[\text{Cr}(\text{H}_2\text{O})_6]\text{Cl}_3$  is 3.83 B.M. Why?

OR

Explain the diamagnetic nature of  $[\text{Ni}(\text{CN})_4]^{2-}$  ion.

32. Arrangement of ligands in order of their ability to cause splitting ( $\Delta$ ) is called spectrochemical series. Ligands which cause large splitting (large  $\Delta$ ) are called strong field ligands while those which cause small splitting (small  $\Delta$ ) are called weak field ligands. When strong field ligands approach metal atom/ion, the value of  $\Delta_o$  is large, so that electrons are forced to get paired up in lower energy  $t_{2g}$  orbitals. Hence, a low-spin complex is resulted from strong field ligand. When weak field ligands approach metal atom/ion, the value of  $\Delta_o$  is small, so that electrons enter high energy  $e_g$  orbitals rather than pairing in low energy  $t_{2g}$  orbitals. Hence, a high-spin complex is resulted from weak field ligands. Strong field ligands have tendency to form inner orbital complexes by forcing the electrons to pair up. Whereas weak field ligands have tendency to form outer orbital complex because inner electrons generally do not pair up.

## Answer the following questions :

**a.**  $[\text{FeF}_6]^{3-}$  is a high spin complex.

**b.** In a high spin situation, configuration of  $d^5$  ion will be  $t_{2g}^3 e_g^2$ .

**c.** The CFSE of  $[\text{Co}(\text{CN})_6]^{3-}$  is greater than that of  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$  ion.

OR

What is meant by crystal field splitting energy? On the basis of crystal field theory, write the electronic configuration of  $d^4$  in terms of  $t_{2g}$  and  $e_g$  in an octahedral field when  $\Delta_o > P$ .

## SECTION E

The following questions are long answer type and carry 5 marks each. Two questions have an internal choice.

OR

(i) Using crystal field theory, draw energy level diagram, write electronic configuration of the central metal atom/ion and determine the magnetic moment value in the following :

(a)  $[\text{CoF}_6]^{3-}$ , (b)  $[\text{FeF}_6]^{3-}$ , (c)  $[\text{Fe}(\text{CN})_6]^{4-}$

(ii)  $\text{FeSO}_4$  solution mixed with  $(\text{NH}_4)_2\text{SO}_4$  solution in 1:1 molar ratio gives the test of  $\text{Fe}^{2+}$  ion but  $\text{CuSO}_4$  solution mixed with aqueous ammonia in 1 : 4 molar ratio does not give the test of  $\text{Cu}^{2+}$  ion. Explain why?

34. (i) Why are different colours observed in octahedral and tetrahedral complexes for the same metal and same ligands?

(ii) Violet coloured  $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$  becomes bright blue when reduced to  $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$ .

(iii) Arrange the following ligands in the order of increasing field strength in spectro chemical series.  $\text{NH}_3$ ,  $\text{CN}^-$ ,  $\text{CO}$ ,  $\text{H}_2\text{O}$

OR

**(i)** Write the hybridisation and magnetic character of the following complexes:

(a)  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$       (b)  $[\text{Ni}(\text{CN})_4]^{2-}$

[Atomic number : Fe = 26, Ni = 28]

**(ii)** Give two examples of coordination compounds used in industries.

35. For the complex  $[\text{Fe}(\text{en})_2\text{Cl}_2]\text{Cl}$ , identify the following:

- (i) Oxidation number of iron
- (ii) Hybrid orbitals and shape of the complex
- (iii) Magnetic behaviour of the complex
- (iv) Number of its geometrical isomers
- (v) Whether there may be optical isomer also.
- (vi) Name of the complex.

## SOLUTIONS

1. (b)

2. (d) :  $(MA_4)^{n+}$  complex cannot show geometrical isomerism as the all possible spatial arrangements of ligands around metal cation is the same.

3. (a)

4. (c) 5. (a)

6. (a) : Oxidation state of Mn in  $[\text{MnO}_4]^- = +7$ , hence it does not has any  $d$ -electron present in it.  
 $\text{Mn}^{7+} (Z = 25) : [\text{Ar}] 3d^0 4s^0$

7. (b) : Ethane-1, 2-diamine (*en*) is a bidentate ligand.

8. (c)

9. (a) : In  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ , oxidation state of Co = +2,  $\text{Co}^{2+} = 3d^7 \therefore t_{2g}^5 e_g^2 [n = 3]$   
 $\mu = \sqrt{n(n+2)} = \sqrt{3(3+2)} = \sqrt{15} = 3.87 \text{ B.M.}$

10. (d)

11. (a) 12. (b)

13. (b) :  $\text{RhCl}(\text{PPh}_3)_3$ , (Wilkinson's catalyst) is used for homogeneous hydrogenation.

14. (a) 15. (a)

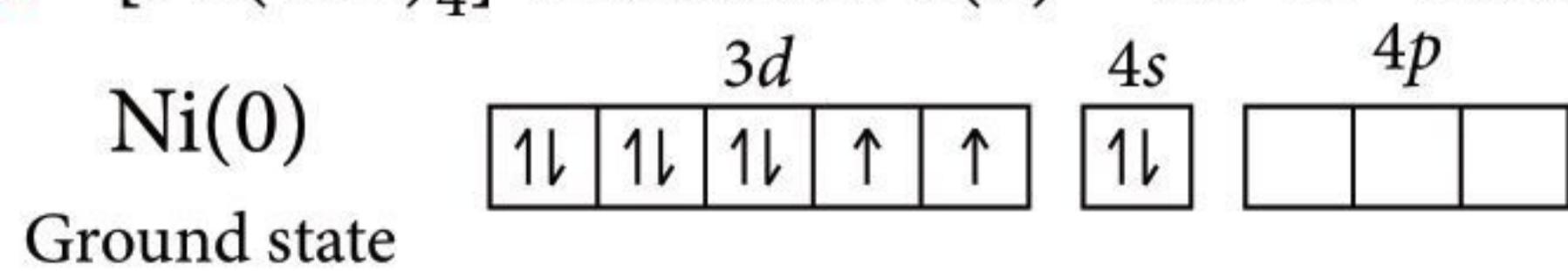
16. (b) :  $[\text{Cu}(\text{NH}_3)_4]^{2+}$  is coloured due to the presence of unpaired electron whereas  $[\text{Cu}(\text{CN})_4]^{3-}$  has no unpaired electron.

17. (b) 18. (b)

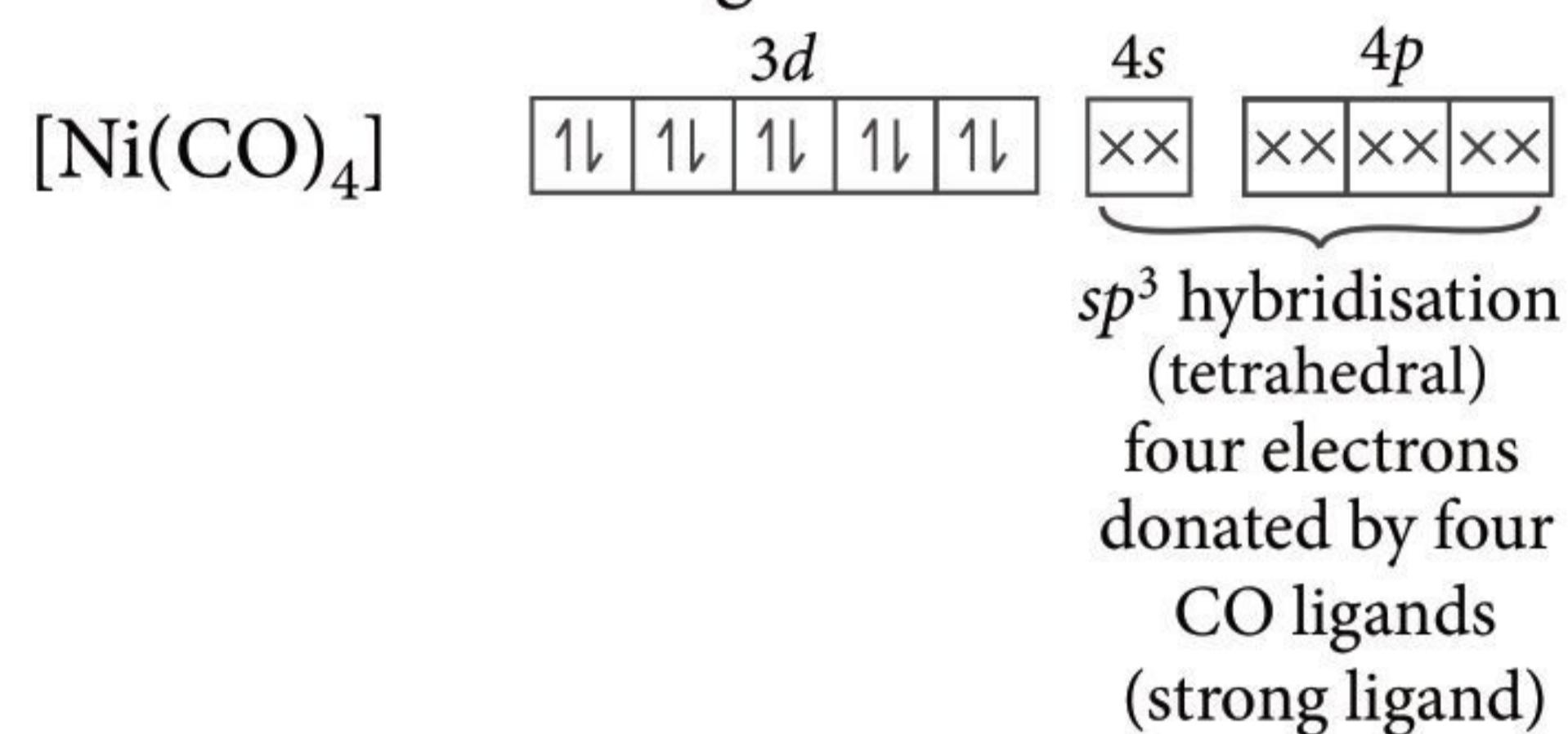
19. a.  $[\text{Co}(\text{NH}_3)_5(\text{ONO})]\text{Cl}_2$  b.  $\text{K}_2[\text{Ni}(\text{CN})_4]$

20. a. For  $d^4$  ion, if  $\Delta_o < P$ , the fourth electron enters one of the  $e_g$  orbitals giving the configuration  $t_{2g}^3 e_g^1$ . Ligands for which  $\Delta_o < P$  are known as weak field ligands and form high spin complexes.

b.  $[\text{Ni}(\text{CO})_4]$  contains  $\text{Ni}(0) - 3d^8 4s^2$  configuration.



CO is a strong field ligand hence, 4s-electrons will shift to 3d-orbital making 4s-orbital vacant.



The complex has all paired electrons hence, it is diamagnetic.

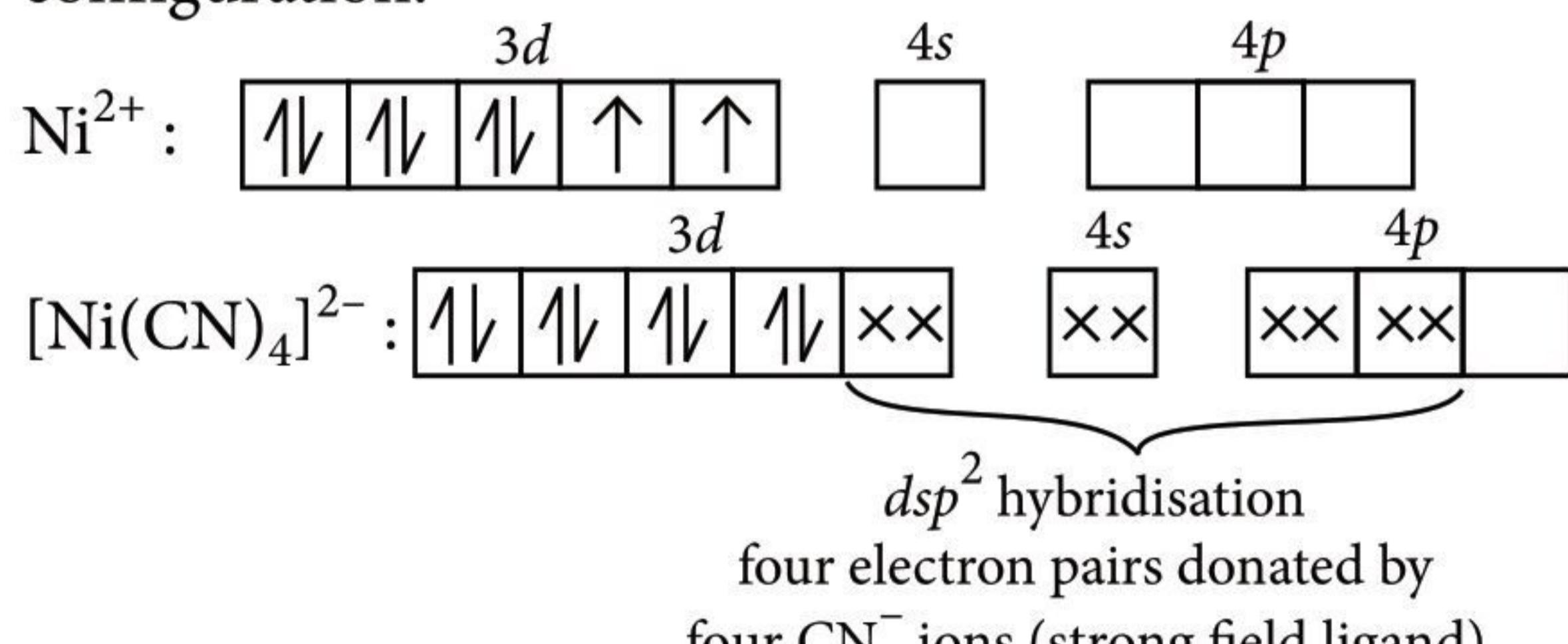
OR

S. NO.	Complex	Central metal ion/ atom	Hybridisation of metal ion involved	Geometry of complex	Magnetic behaviour
a.	$[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$	$\text{Cr}^{3+}$	$d^2sp^3$	Octahedral	Paramagnetic
b.	$[\text{Co}(\text{en})_3]\text{Cl}_3$	$\text{Co}^{3+}$	$d^2sp^3$	Octahedral	Diamagnetic

21. Electronic configuration :  $t_{2g}^4 e_g^2$ . This complex is paramagnetic due to the presence of four unpaired electrons as  $\text{H}_2\text{O}$  is a weak field ligand.

OR

a. In  $[\text{Ni}(\text{CN})_4]^{2-}$  : Ni is present as  $\text{Ni}^{2+}$  with  $3d^8$  configuration.



$\therefore$  The complex ion has square planar geometry.

b.  $\text{Cu}(\text{Z} = 29) : [\text{Ar}] 3d^9 4s^2$   
 $\text{Cu}^{2+} : 3d^9$

Number of unpaired electron = 1

$$\text{Magnetic moment, } \mu_B = \sqrt{n(n+2)}$$

$$= \sqrt{1(1+2)} = 1.73 \text{ B.M.}$$

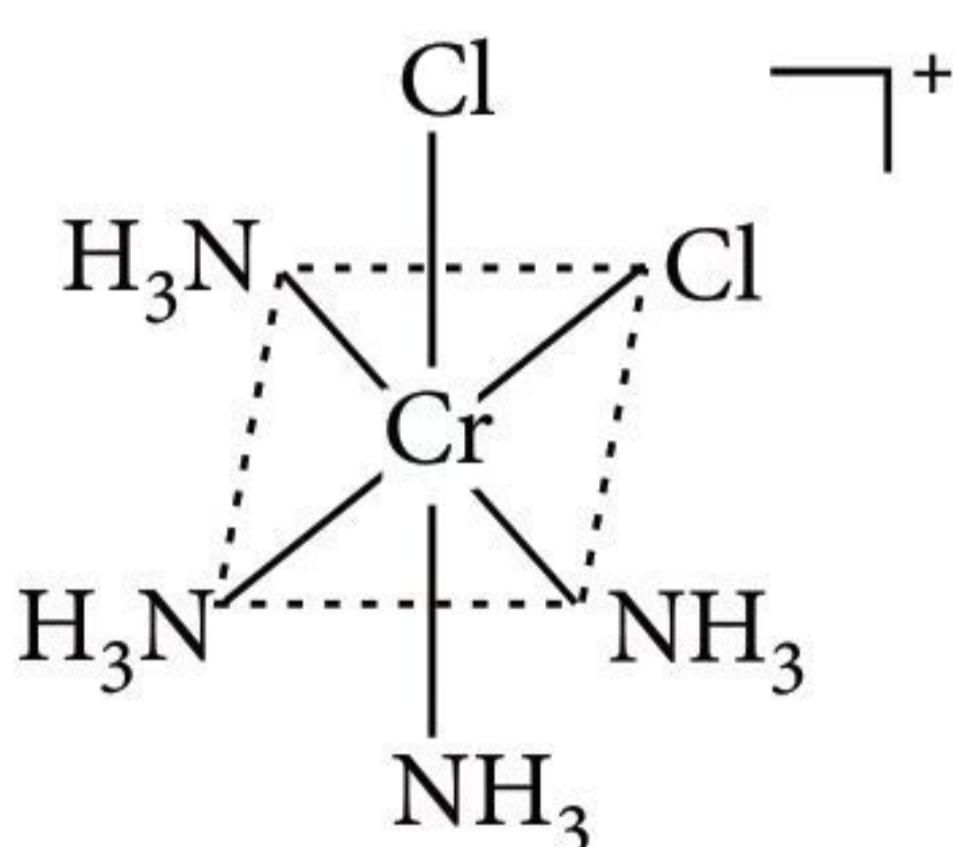
22. Due to the presence of weak field ligand, i.e.,  $\text{Cl}^-$  in the complex  $[\text{NiCl}_4]^{2-}$ , two unpaired electrons are present in 3d-orbitals of Ni-atom hence, this complex is paramagnetic in nature. On the other hand, due to the presence of strong field ligand i.e.,  $\text{CN}^-$  in the complex  $[\text{Ni}(\text{CN})_4]^{2-}$ , no unpaired electron is present in 3d-orbitals of Ni-atom (as strong field ligand causes pairing of electrons), hence, it is diamagnetic in nature.

23. a.  $\text{K}_2[\text{PdCl}_4]$  : Potassium tetrachloridopalladate(II)  
b. If  $\Delta_o > P$ , it becomes energetically favourable for the fourth and fifth electron to occupy in  $t_{2g}^5$  orbital with the resultant configuration  $t_{2g}^5 e_g^0$ . Such an effect is produced by strong field ligand and such a complex formed is referred to as low spin complex.

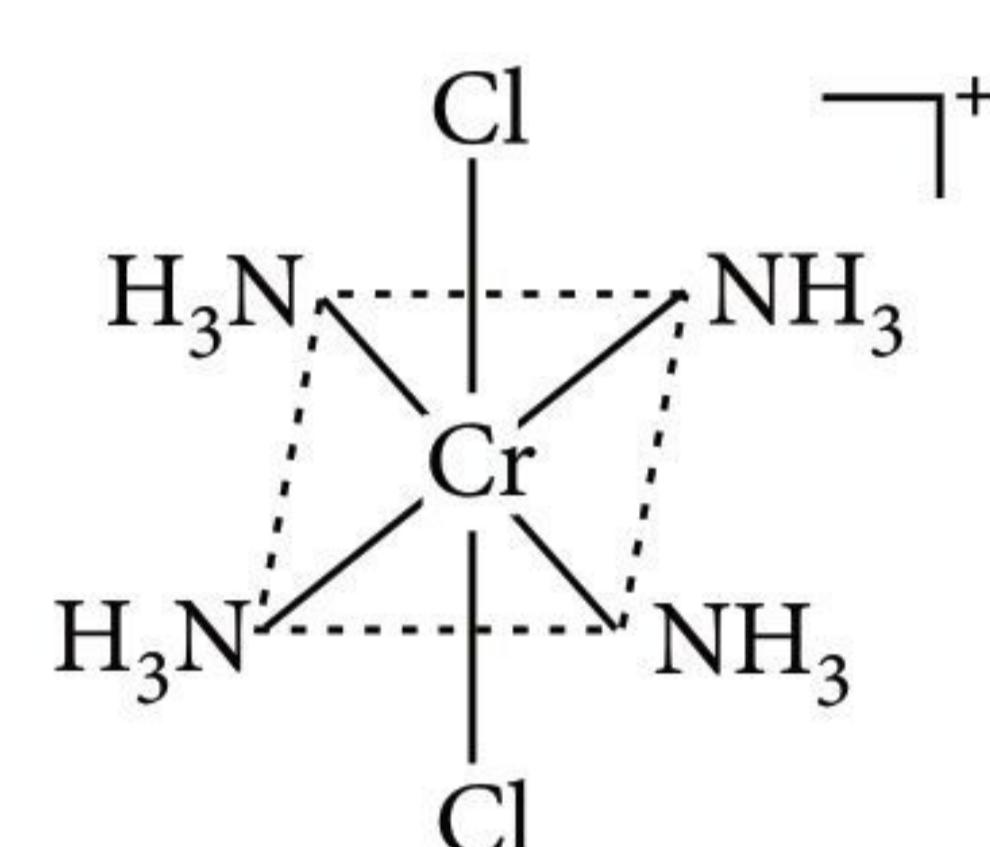
24. a.  $\text{Na}[\text{Au}(\text{CN})_2]$

b.  $[\text{Pt}(\text{NH}_3)_4(\text{Cl})(\text{NO}_2)]\text{SO}_4$

25. Tetraamminedichloridochromium(III) ion  
Geometrical isomers of  $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]^+$ :



cis-Tetraamminedichloridochromium(III) ion



trans-Tetraamminedichloridochromium(III) ion

26. (a)  $[\text{FeF}_6]^{3-}$

Oxidation state of Fe = +3

$\text{F}^-$  being weak field ligand, no pairing occurs.

$\text{Fe}^{3+} : 3d^5$ ,

3d-orbitals

$$\mu_{\text{spin}} = \sqrt{n(n+2)} \text{ B.M.} = \sqrt{5(5+2)} \text{ B.M.} = 5.91 \text{ B.M.}$$

(b) Pentaamminechloridocobalt(III) chloride

(c) Chelating ligands form more stable cyclic/ring complexes than unidentate or non-chelating ligands. Since  $[\text{Co}(\text{en})_3]^{3+}$  contains en which is a bidentate chelating ligand, it is more stable than  $[\text{CoF}_6]^{3-}$ .

27. Refer to Page no. 225, Class-12, MTG 100 percent Chemistry.

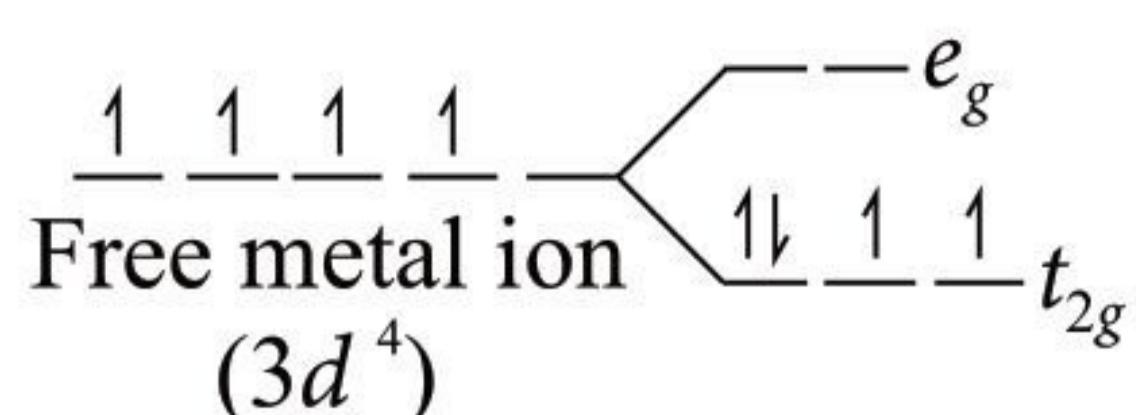
28. Refer to answer 39, page no. 116, Class-12, MTG CBSE Champion Chemistry.

29. Refer to answer 18, page no. 238, Class-12, MTG 100 percent Chemistry.

30. a. Refer to Page no. 222, Class-12, MTG 100 percent Chemistry.

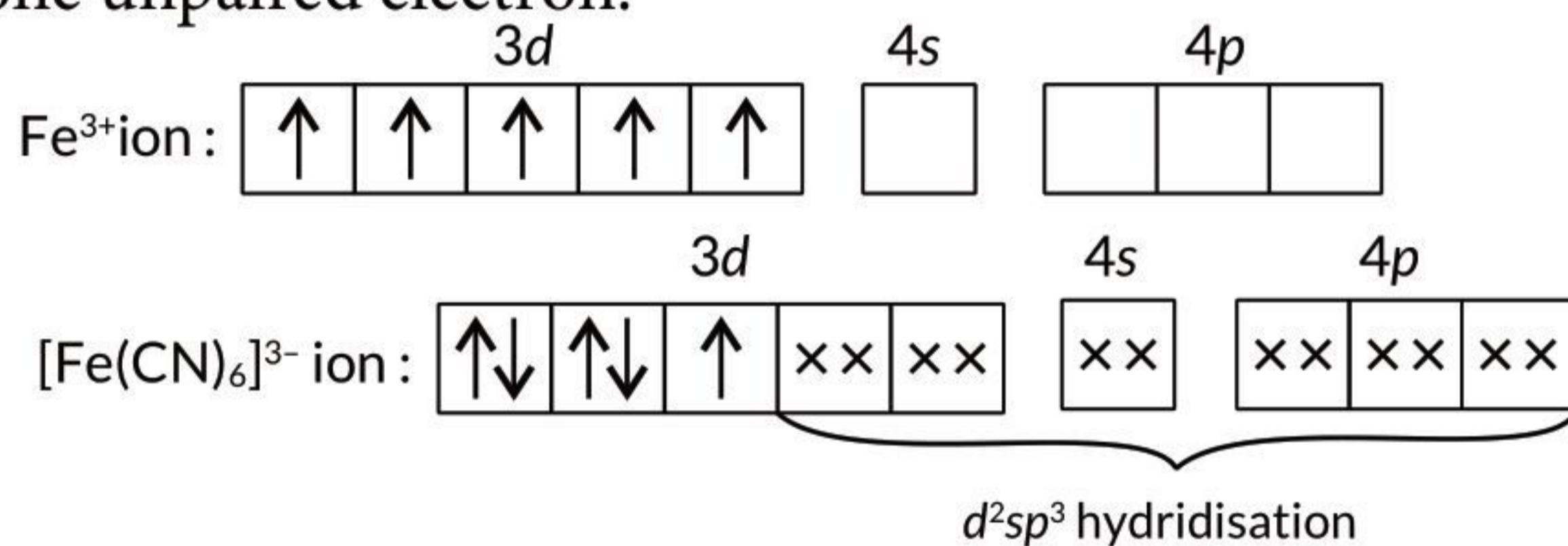
b. In  $[\text{Mn}(\text{CN})_6]^{3-}$ , Mn is in +3 state so, it has configuration of  $3d^4$ .

Since  $\text{CN}^-$  is a strong field ligand hence pairing of electrons in 3d-orbital takes place.



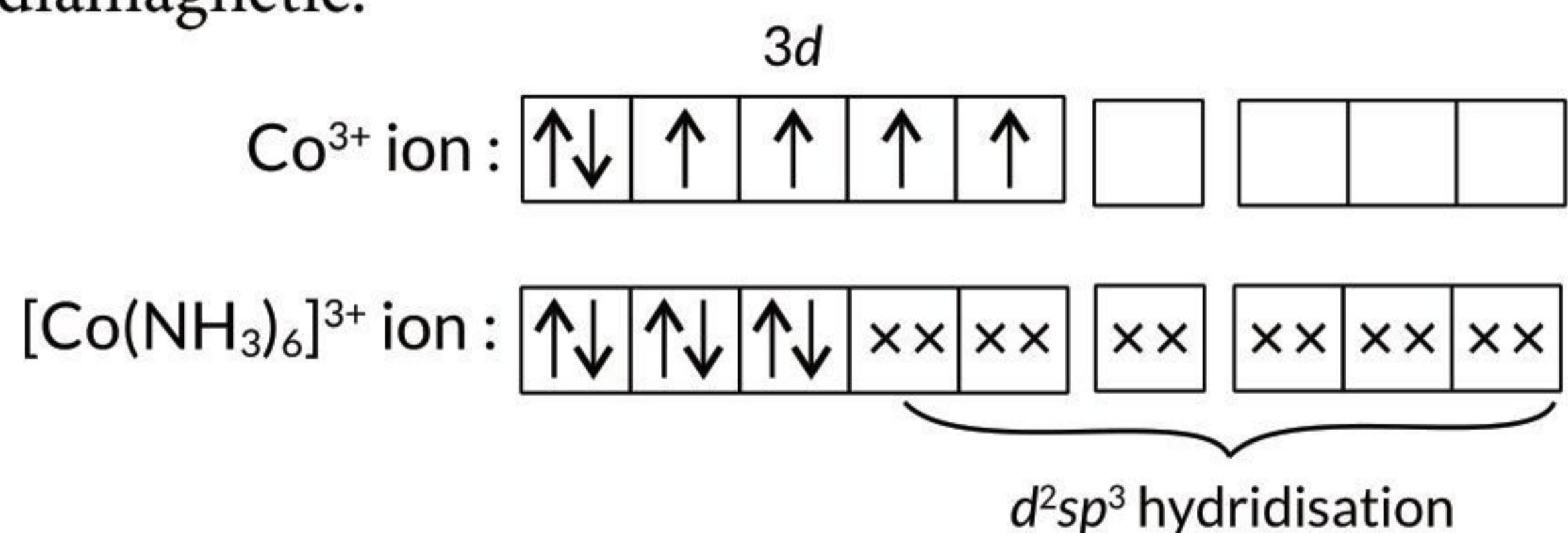
So,  $[\text{Mn}(\text{CN})_6]^{3-}$  has two unpaired electrons. But in  $[\text{MnCl}_6]^{3-}$ ,  $\text{Cl}^-$  is a weak field ligand, so no pairing takes place and it has 4 unpaired electrons.

c. Formation of hexacyanidoferate(III) ion;  $[\text{Fe}(\text{CN})_6]^{3-}$  : Electronic configuration of iron in the ground state is  $3d^64s^2$ . The oxidation state of iron is +3 in this complex. Iron(III) has outer electronic configuration  $3d^54s^0$ . It has been experimentally observed that this complex has one unpaired electron. To account for this, two unpaired electrons in  $3d$  subshell pair up, thus leaving two  $3d$ -orbitals empty. These two vacant  $3d$ -orbitals, along with one  $4s$ -orbital and three  $4p$ -orbitals hybridise to give six equivalent  $d^2sp^3$  hybridised orbitals. Six pairs of electrons, one from each cyanide ion, occupy the six vacant hybrid orbitals so produced. The complex has octahedral geometry and is paramagnetic due to the presence of one unpaired electron.

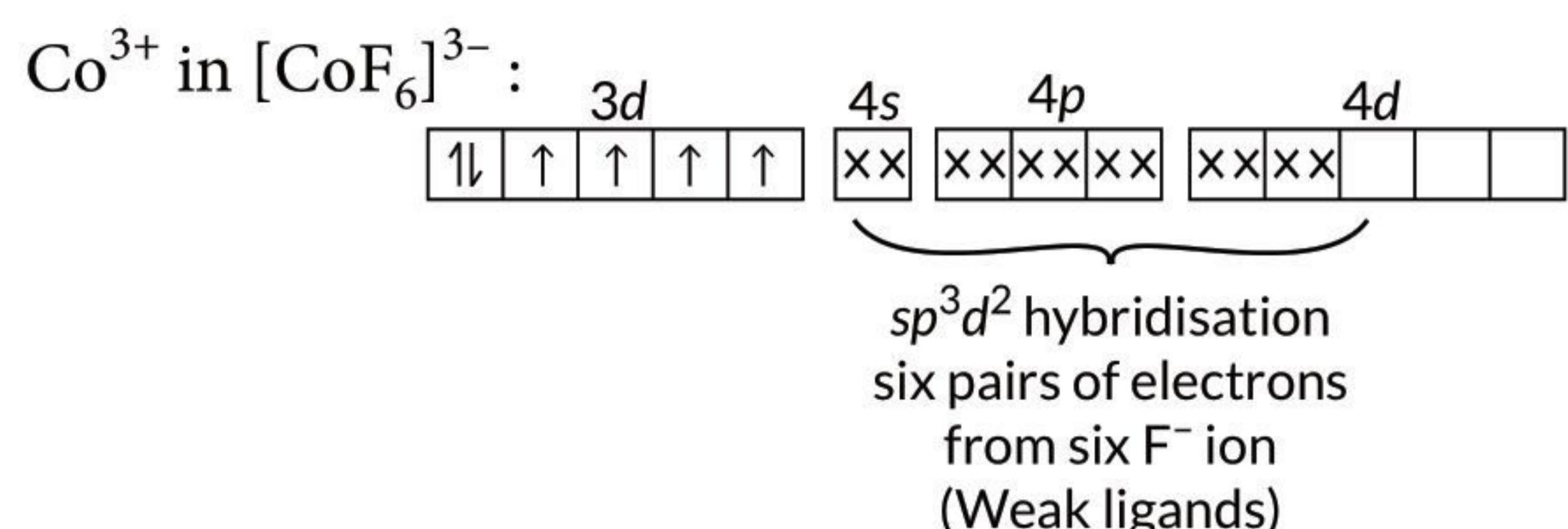
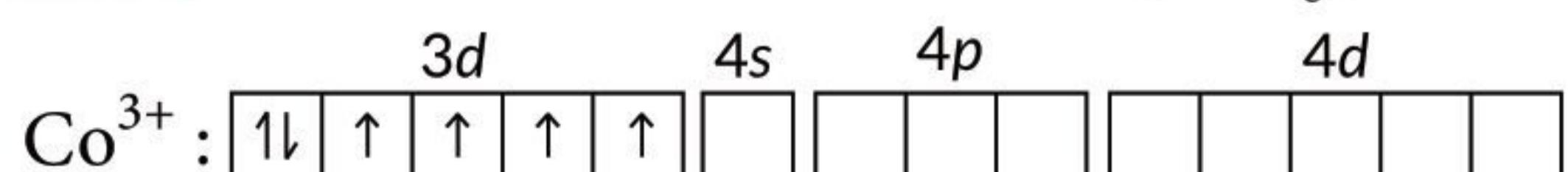


The complex evidently involves  $(n-1)d^2$   $ns$   $np^3$  hybridisation and is, therefore, called inner orbital or low spin complex.

d. The outer electronic configuration of cobalt (III) ion is  $3d^6$ . According to Hund's rule, four of the  $3d$ -orbitals are singly filled and one  $3d$ -orbital has a pair of electrons. Octahedral complexes are formed through  $d^2sp^3$  hybridisation for which the metal atom must have two of its  $3d$ -orbitals empty. This is achieved by the pairing of the two  $3d$ -electrons as a result of the energy released due to the approach of the ligands. This results in the formation of an octahedral complex. As it is evident from the figure given below, the complex does not contain any unpaired electron and is, therefore, diamagnetic.



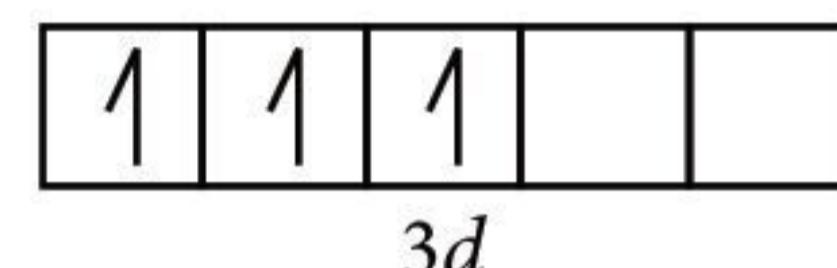
31. a. Oxidation state of Co ion in  $[\text{CoF}_6]^{3-}$  is +3.



No. of unpaired electrons = 4, hence the given complex ion is paramagnetic.

b. The complex  $[\text{Co}(\text{C}_2\text{O}_4)_3]^{3-}$  has  $d^2sp^3$ -hybridisation and it is diamagnetic in nature due to the absence of unpaired electrons.

c. The oxidation state of Cr in the given complex is +3. This means the electronic configuration of Cr<sup>3+</sup> is  $[\text{Ar}]3d^3$ .



Since the number of unpaired electrons is 3, this implies,

$$\begin{aligned} \text{Magnetic movement } (\mu) &= \sqrt{n(n+2)} \\ &= \sqrt{3(3+2)} \\ &= \sqrt{3(5)} \\ &= \sqrt{15} = 3.83 \text{ B.M.} \end{aligned}$$

OR

d. In  $[\text{Ni}(\text{CN})_4]^{2-}$ , the oxidation state of Ni is +2, therefore, 8 electrons are present in  $d$ -orbitals out of which 2 are unpaired. Under the influence of ligand molecules ( $\text{CN}^-$ ) these unpaired electrons are forced to pair and one  $d$ -orbital becomes vacant before undergoing  $dsp^2$  hybridisation. Four electron pairs from ligand molecules are donated to four  $dsp^2$  hybridised orbitals. Because there is no unpaired electron in  $[\text{Ni}(\text{CN})_4]^{2-}$ , therefore, it is diamagnetic in nature having square planar geometry.

32. a. Since  $\text{F}^-$  is a weak field ligand, it does not cause pairing of  $3d$ -electrons of Fe, hence the complex undergoes  $sp^3d^2$  hybridisation and is a high spin complex.  $\text{F}^-$  ion cannot force the electrons of  $d_z^2$  and  $d_{x^2-y^2}$  orbitals of the inner shell to occupy  $d_{xy}$ ,  $d_{yz}$  and  $d_{zx}$  orbitals of the same shell.

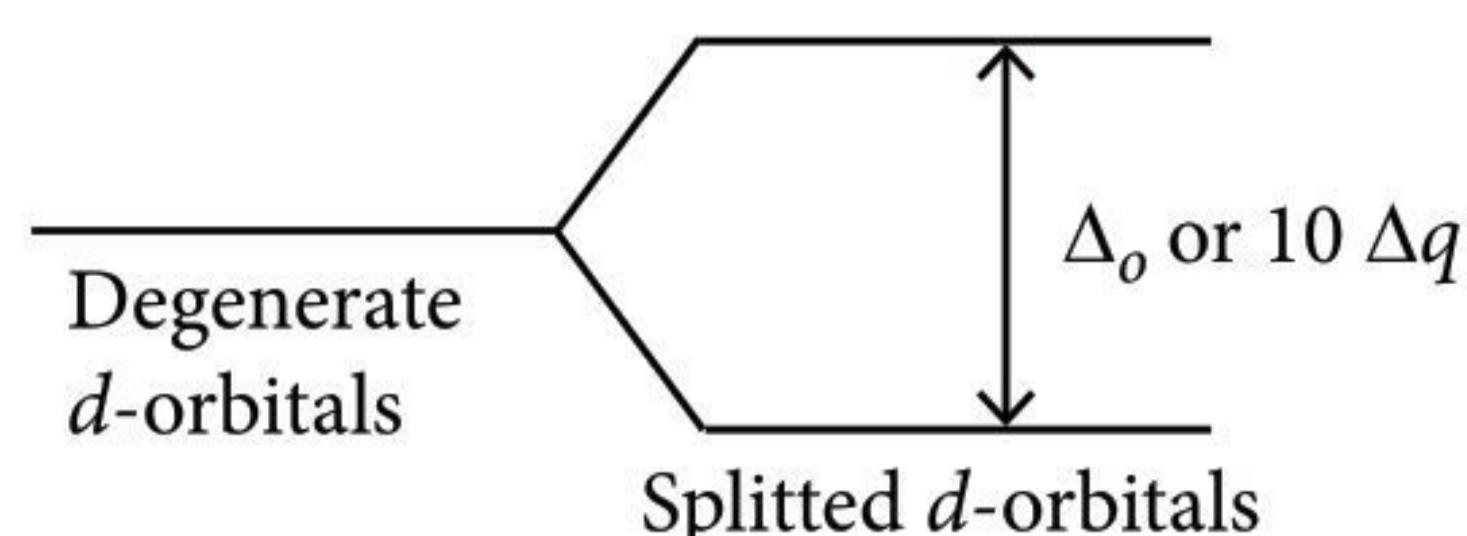
b. In a high spin situation, the electrons of the higher energy  $e_g$  orbital are unable to pair with the electrons in the  $t_{2g}$  orbital due to high pairing energy as compared to the crystal field energy. Hence the configuration of  $d^5$  ion will be  $t_{2g}^3 e_g^2$ .

c.  $\text{CN}^-$  is a strong field ligand while  $\text{H}_2\text{O}$  is a weak field ligand. Thus  $\text{CN}^-$  causes larger splitting, i.e., larger  $\Delta_o$  as compared to  $\text{H}_2\text{O}$  ligand.

OR

The difference of energy between two splitted levels of  $d$ -orbitals is called crystal field splitting energy. It is denoted by  $\Delta_o$  or  $10\Delta_q$ .

For octahedral  $\Delta_o$ , for tetrahedral it is  $\Delta_t$  and for square planar  $\Delta_{sp}$ .



When  $\Delta_o > P$ , the d-orbital electronic configuration is  $t_{2g}^4 e_g^0$ .

33. Refer to answer 48, page no. 118, Class-12, MTG CBSE Champion Chemistry.

34. (i) Lower wavelength is absorbed in octahedral complex than tetrahedral complex for the same metal and ligand. In tetrahedral coordination entity, formation of the d-orbital splitting is inverted and is smaller as compared to the octahedral field splitting. For the same metal-ligand complexes, it can be shown that  $\Delta_t = (4/9)\Delta_o$ .

(ii)  $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$  violet coloured changes to blue coloured  $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$  when reduced because its  $\Delta_o$  gets lowered and due to which in place of yellow region absorbed by  $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$  now orange red region is absorbed and hence  $[\text{Cr}(\text{H}_2\text{O})_6]^{2+}$  becomes blue as blue is the complementary colour of orange.

(iii) Spectrochemical series :  $\text{H}_2\text{O} < \text{NH}_3 < \text{CN}^- < \text{CO}$

OR

(i) (a)  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ :

Fe atom ( $Z = 26$ )

Ground state :  $3d^6 \quad 4s^2 \quad 4p^0$   
 $[\begin{array}{|c|c|c|c|c|c|} \hline 1 & \uparrow & \uparrow & \uparrow & \uparrow & \uparrow \\ \hline \end{array} \quad \begin{array}{|c|} \hline 1 & \uparrow \\ \hline \end{array} \quad \begin{array}{|c|c|c|} \hline \end{array}]$

$\text{Fe}^{2+}$  ion :  $3d^6 \quad 4s \quad 4p$   
 $[\begin{array}{|c|c|c|c|c|c|} \hline 1 & \uparrow & \uparrow & \uparrow & \uparrow & \uparrow \\ \hline \end{array} \quad \begin{array}{|c|} \hline \quad \\ \hline \end{array} \quad \begin{array}{|c|c|c|} \hline \end{array}]$

$[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ :  
 $3d^5 \quad 4s \quad 4p \quad 4d$   
 $[\begin{array}{|c|c|c|c|c|c|} \hline 1 & \uparrow & \uparrow & \uparrow & \uparrow & \uparrow \\ \hline \end{array} \quad \underbrace{\begin{array}{|c|c|c|c|} \hline \times & \times & \times & \times \\ \hline \end{array}}_{sp^3d^2 \text{ hybridisation}} \quad \begin{array}{|c|c|c|} \hline \times & \times & \times \\ \hline \end{array} \quad \begin{array}{|c|c|c|} \hline \end{array}]$

The complex ion has outer orbital octahedral geometry (high spin) and is paramagnetic due to the presence of four unpaired electrons.

(b) In  $[\text{Ni}(\text{CN})_4]^{2-}$  : Ni is present as Ni(II) with  $3d^8$  configuration.

$\text{Ni}^{2+}$ :  $3d^8 \quad 4s \quad 4p$   
 $[\begin{array}{|c|c|c|c|c|c|} \hline 1 & 1 & 1 & \uparrow & \uparrow \\ \hline \end{array} \quad \begin{array}{|c|} \hline \quad \\ \hline \end{array} \quad \begin{array}{|c|c|c|} \hline \end{array}]$   
 (In ground state)  
 $[\text{Ni}(\text{CN})_4]^{2-}$ :  $3d^8 \quad 4s \quad 4p$   
 $[\begin{array}{|c|c|c|c|c|c|} \hline 1 & 1 & 1 & 1 & \times & \times \\ \hline \end{array} \quad \underbrace{\begin{array}{|c|c|c|} \hline \times & \times & \times \\ \hline \end{array}}_{dsp^2 \text{ hybridisation}} \quad \begin{array}{|c|c|c|} \hline \times & \times & \times \\ \hline \end{array}]$

The complex ion has square planar geometry and is diamagnetic in nature.

(ii) (a)  $\text{Na}_2\text{EDTA}$  is used for estimation of hardness of water.

(b) Wilkinson's catalyst is used as catalyst for hydrogenation.

35. (i)  $[\text{Fe}(\text{en})_2\text{Cl}_2]\text{Cl}$

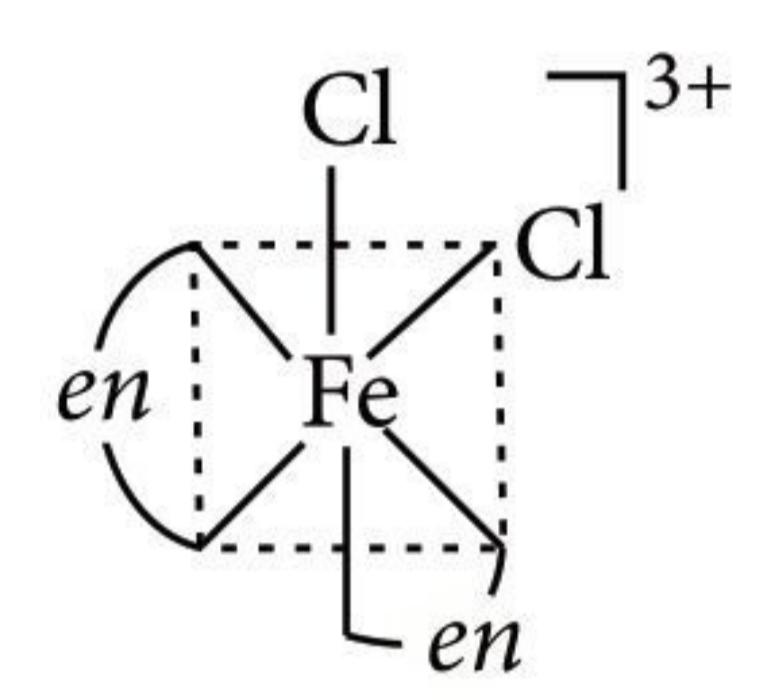
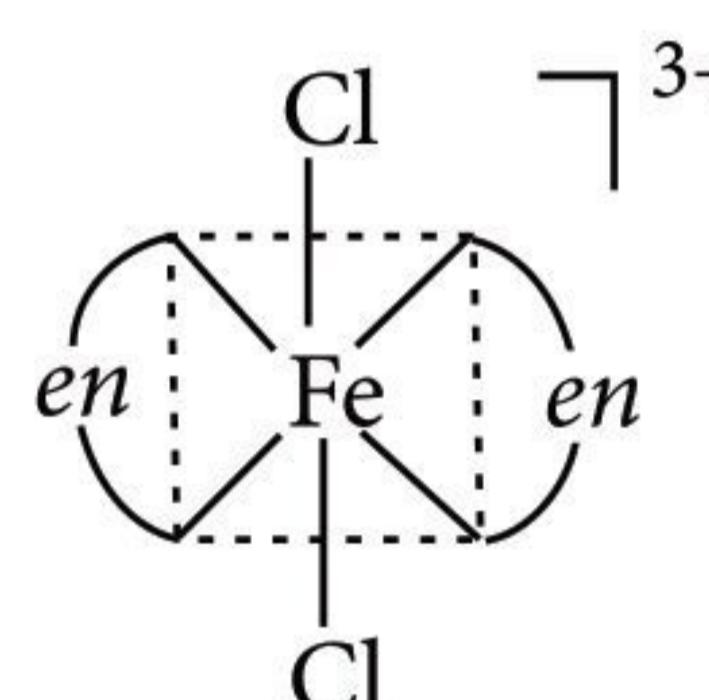
$$x + 0 \times 2 + (-1) \times 2 + (-1) \times 1 = 0. \therefore x = +3$$

Oxidation number of iron = +3

(ii)  $d^2sp^3$  hybridisation and octahedral shape.

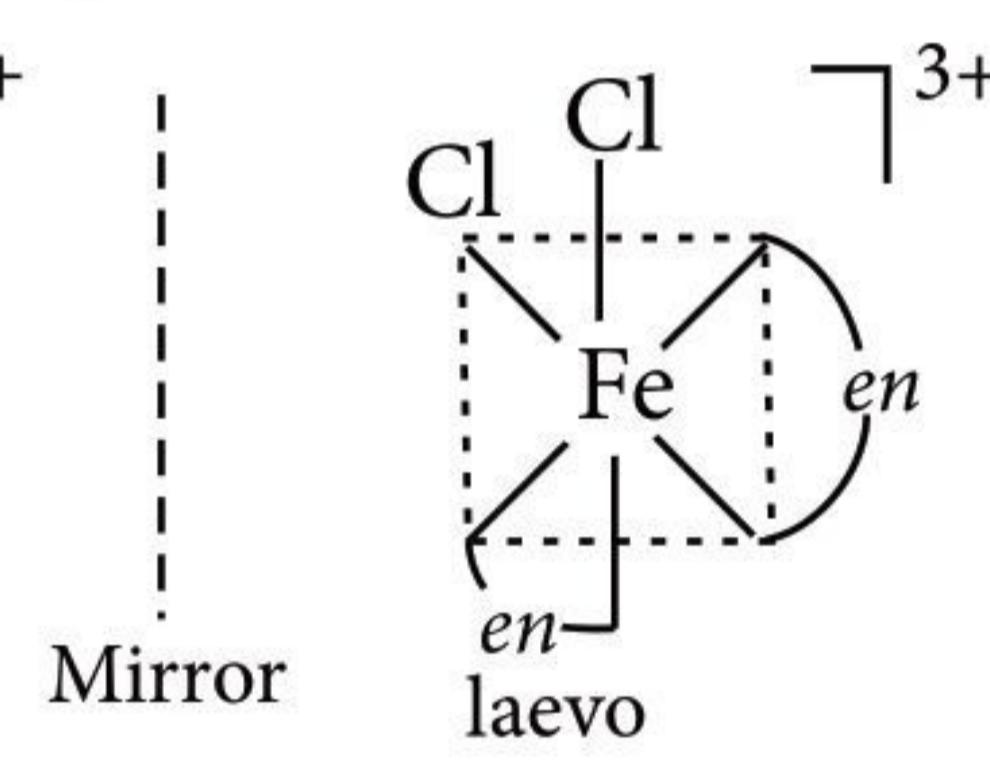
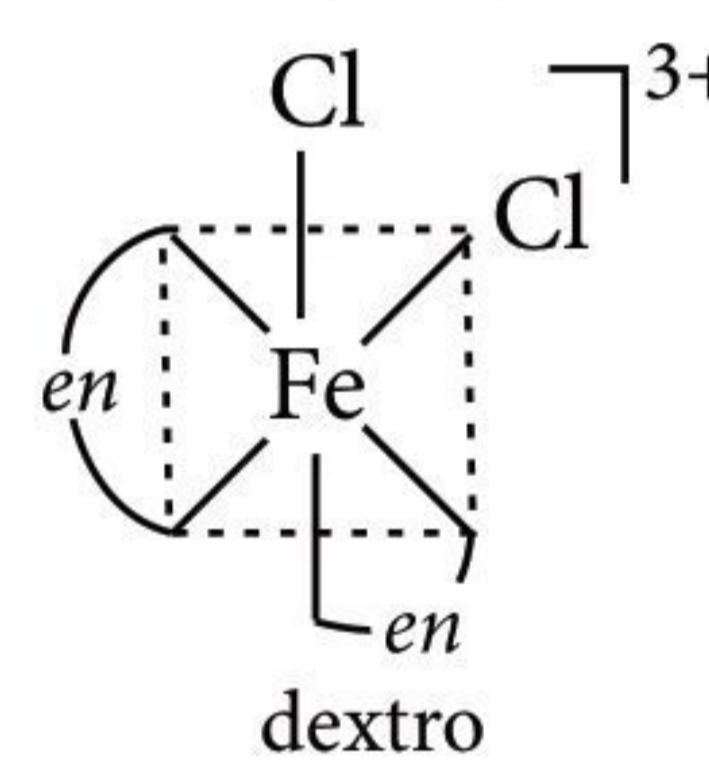
(iii) Paramagnetic due to presence of one unpaired electron.

(iv) 2, *cis*- and *trans*-isomers.



*trans*-bis (ethane-1,2-diamine) dichloridoiron(III) chloride      *cis*-bis (ethane-1,2-diamine) dichloridoiron(III) chloride

(v) *cis*- $[\text{Fe}(\text{en})_2\text{Cl}_2]$  has optical isomer.



(vi) dichloridobis(ethane-1,2-diamine)iron(III)chloride



The same THREE LETTERS will complete these five words.

Can you find the three-letter sequence?

B — — O Q U I N O N E

E T H Y L B — — E N E

B — — O N I T R I L E

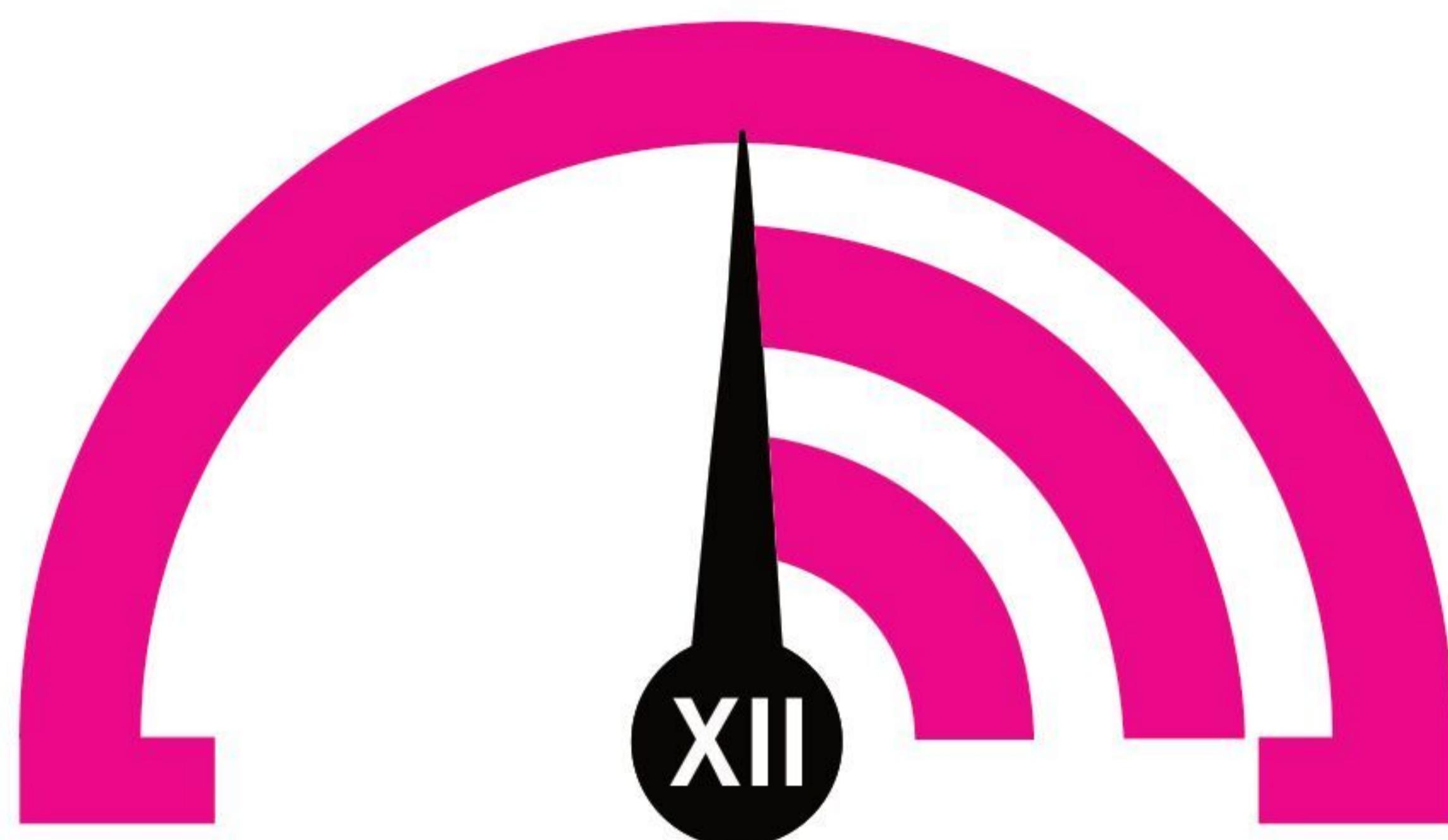
V I N Y L B — — E N E

— — — Y M E S

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Winners' names will be published in next issue.

# MONTHLY TEST DRIVE



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**Total Marks : 120**

## Biomolecules | Polymers

**Time Taken : 60 Min.**

### NEET

#### Only One Option Correct Type

- On oxidation with nitric acid, glucose as well as gluconic acid both yield
 

(a) maleic acid	(b) fumaric acid
(c) saccharic acid	(d) aspartic acid.
- The chemical name of vitamin B<sub>1</sub> is
 

(a) ascorbic acid	(b) riboflavin
(c) pyridoxine	(d) thiamine.
- Which of the following is a condensation polymer?
 

(a) Teflon	(b) Dacron
(c) Polystyrene	(d) Neoprene.
- Select the incorrect statement.
 

(a) Glucose and galactose are epimers at C-4.
(b) Glucose and galactose are epimers at C-2.
(c) Glucose and mannose are epimers at C-2.
(d) All of these
- Which of the following is not correctly matched?
 

(a) Neoprene : $\left[ \begin{array}{c} \text{CH}_2-\text{C}=\text{CH}-\text{CH}_2 \\   \qquad   \\ \text{H} \qquad \text{CH}_3 \end{array} \right]_n$
(b) Nylon-66 : $\left[ \begin{array}{c} \text{NH}-(\text{CH}_2)_6-\text{NH}-\text{CO}-(\text{CH}_2)_4-\text{C}=\text{O} \end{array} \right]_n$
(c) Terylene : $\left[ \begin{array}{c} \text{OCH}_2-\text{CH}_2\text{O}-\text{C}(=\text{O})-\text{C}_6\text{H}_4-\text{C}(=\text{O}) \end{array} \right]_n$
(d) PMMA : $\left[ \begin{array}{c} \text{CH}_3 \\   \\ \text{CH}_2-\text{C}- \\   \\ \text{COOCH}_3 \end{array} \right]_n$

- Which of the following contains ester linkage?
 

(a) Bakelite	(b) Terylene (dacron)
(c) Nylon-66	(d) Polythene.
- Sucrose is not a reducing sugar since
 

(a) it is chemically stable
(b) it contains no free aldehyde or keto group adjacent to $\text{>CHOH}$ group
(c) it is built up of a fructose unit
(d) it is optically active.
- Dimethyl terephthalate and ethylene glycol react to form
 

(a) neoprene	(b) nylon-66
(c) dacron	(d) nylon-6.
- Mark the incorrect example.
 

(a) Keratin and myosin - Fibrous proteins
(b) Insulin and albumins - Globular proteins
(c) Glycylalanine - Dipeptide
(d) Enzymes and haemoglobin - Derived proteins.
- The polymer used for making unbreakable cups and plates is
 

(a) Urea-formaldehyde resin
(b) polyethylene
(c) polyethyl acrylate
(d) nylon 6.
- The monomer of polystyrene is
 

(a) $\text{C}_2\text{H}_5-\text{CH}=\text{CH}_2$	(b) $\text{CH}_2\text{CH}=\text{CH}_2$
(c) $\text{C}_6\text{H}_5-\text{CH}=\text{CH}_2$	(d) $\text{CH}_2\text{CH}=\text{CHO}$
- The pyrimidine bases present in DNA are
 

(a) cytosine and adenine
(b) cytosine and guanine
(c) cytosine and thymine
(d) cytosine and uracil.

### Assertion & Reason Type

**Directions :** In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as :

- If both assertion and reason are true and reason is the correct explanation of assertion.
- If both assertion and reason are true but reason is not the correct explanation of assertion.
- If assertion is true but reason is false.
- If both assertion and reason are false.

**13. Assertion :** Fructose is a reducing sugar.

**Reason :** Fehling's solution on treatment with fructose gives brick red ppt.

**14. Assertion :** An aqueous solution of glycine at pH = 7 is not electrically neutral.

**Reason :** The isoelectric point of glycine, PI is 6.

**15. Assertion :** Bakelite is a thermosetting polymer.

**Reason :** Bakelite can be reused.

### JEE MAIN / JEE ADVANCED

#### Only One Option Correct Type

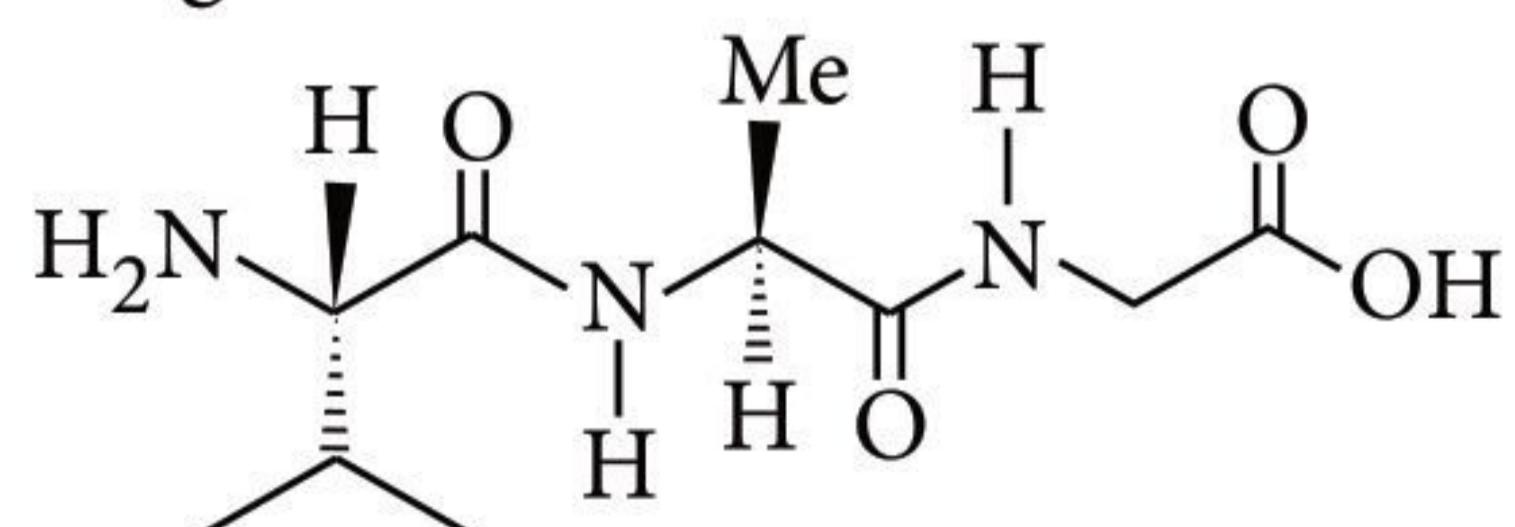
**16.** Thiamine and pyridoxine are also known respectively as

- Vitamin B<sub>1</sub> and Vitamin B<sub>6</sub>
- Vitamin E and Vitamin B<sub>2</sub>
- Vitamin B<sub>2</sub> and Vitamin E
- Vitamin B<sub>6</sub> and Vitamin B<sub>2</sub>

**17.** Novolac, the linear polymer used in paints is

- copolymer of 1, 3-butadiene and styrene
- obtained by the polymerisation of methyl methacrylate
- initial product obtained in the condensation of phenol and formaldehyde in the presence of acid catalyst
- obtained by the polymerisation of caprolactam

**18.** The following tripeptide can be synthesized from the following amino acids



- Glycine, Leucine and Alanine
- Alanine, Isoleucine and Glycine
- Valine, Alanine and Glycine
- Alanine, Serine and Glycine.

**19.** Which of the following is a biodegradable polymer?

- $\left[ \text{HN} - (\text{CH}_2)_6 \text{NHCO} - (\text{CH}_2)_4 - \text{C} \right]_n$
- $\left[ \text{HN} - (\text{CH}_2)_5 \text{CONH} - \text{CH}_2 - \text{C} \right]_n$
- $\left[ \text{HN} - (\text{CH}_2)_5 - \text{C} \right]_n$
- $\left[ \text{C} = \text{O} - \text{C}_6\text{H}_4 - \text{COO} - (\text{CH}_2)_2 - \text{O} \right]_n$

#### More than One Option Correct Type

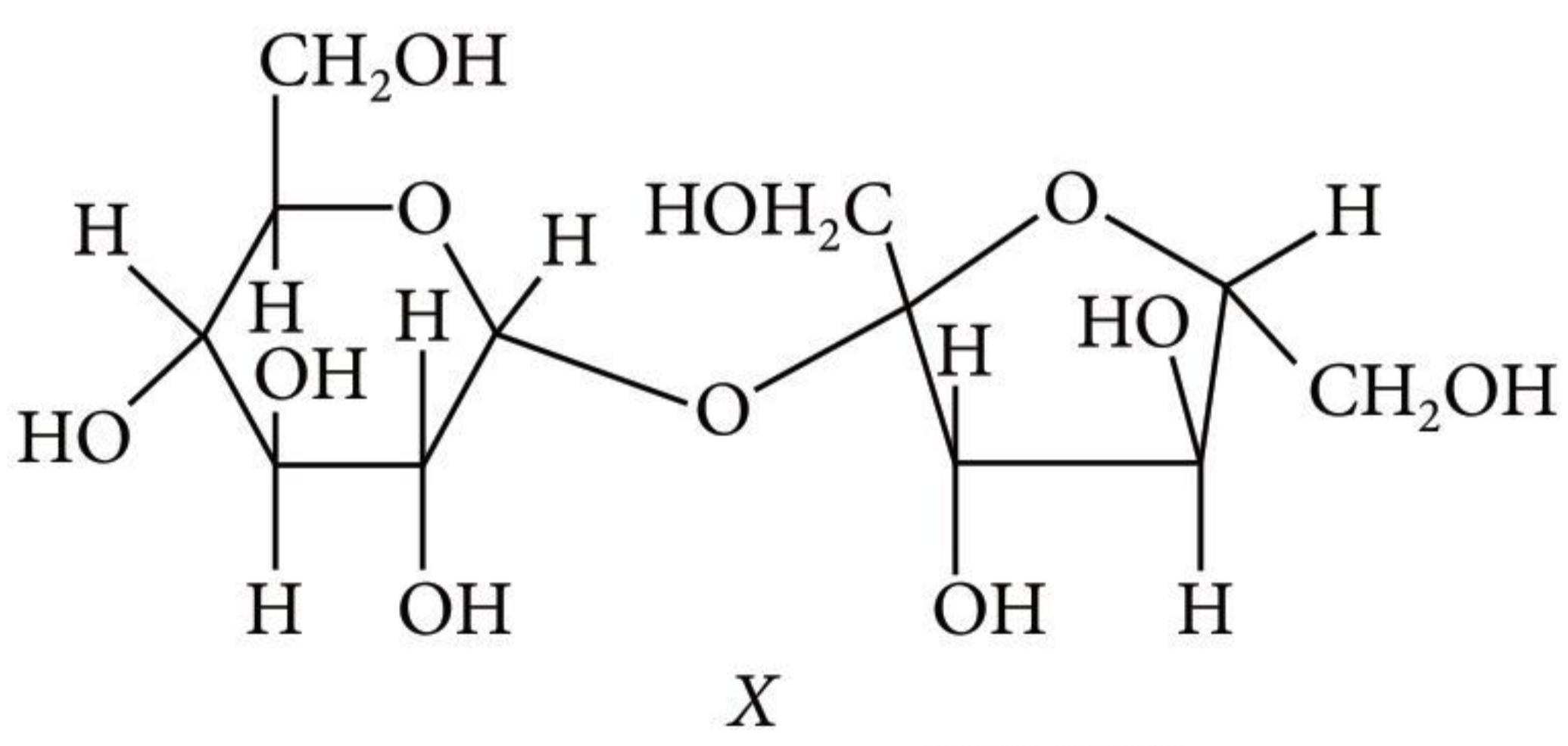
**20.** Which of the following statement(s) is(are) true?

- The two six-membered cyclic hemiacetal forms of D-(+)-glucose are called anomers.
- Hydrolysis of sucrose gives dextrorotatory glucose and laevorotatory fructose.
- Monosaccharides cannot be hydrolysed to give polyhydroxy aldehydes and ketones.
- Oxidation of glucose with bromine water gives glutamic acid.

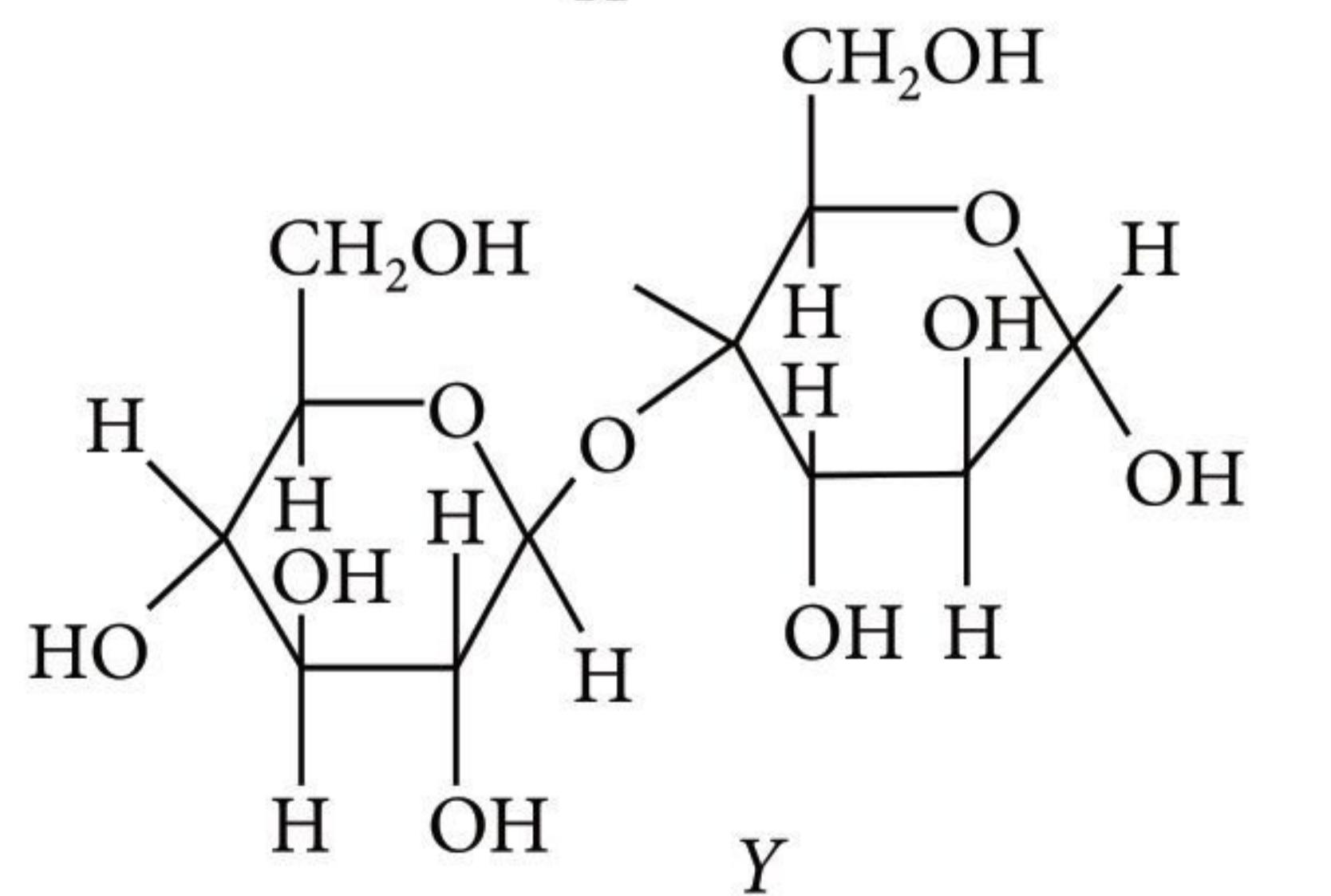
**21.** Which of the following statements is not true?

- Nylon-6 is an example of step-growth polymerisation.
- Chain growth polymerisation involves homopolymerisation only.
- Step-growth polymerisation requires a bifunctional monomer.
- Chain growth polymerisation includes both homopolymerisation and copolymerisation.

**22.** The correct statement(s) about the following sugars X and Y is(are)



X



Y

(a)  $X$  is a reducing sugar and  $Y$  is a non-reducing sugar  
 (b)  $X$  is a non-reducing sugar and  $Y$  is a reducing sugar  
 (c) the glycosidic linkages in  $X$  and  $Y$  are  $\alpha$  and  $\beta$  respectively  
 (d) the glycosidic linkages in  $X$  and  $Y$  are  $\beta$  and  $\alpha$  respectively.

23. Which of the following is not true?  
 (a) In vulcanisation the rubber becomes harder and stronger.  
 (b) Natural rubber has 'trans' configuration at every double bond.  
 (c) Buna-S is a copolymer of butene and styrene.  
 (d) Natural rubber is 1,4-polymer of isoprene.

#### Integer / Numerical Value Type

24. The number of chiral carbons present in sucrose is \_\_\_\_\_.  
 25. The total number of lone pair of electrons in melamine is \_\_\_\_\_.  
 26. A peptide synthesised by the reactions of one molecule each of glycine, leucine, aspartic acid and histidine will have \_\_\_\_\_ peptide linkages.

#### Comprehension Type

When a protein in its native form, is subjected to physical changes like change in temperature or chemical changes like change in pH, the hydrogen bonds are disturbed. Due to this, globules unfold and helix get uncoiled and protein loses its biological activity. This is called denaturation of protein.

The denaturation causes change in secondary and tertiary structures but primary structures remains intact. Examples of denaturation of protein are coagulation of egg white on boiling, curdling of milk, formation of cheese when an acid is added to milk.

27. Which structure(s) of proteins remains(s) intact during denaturation process?  
 (a) Both secondary and tertiary structures  
 (b) Primary structure only  
 (c) Secondary structure only  
 (d) Tertiary structure only

28.  $\alpha$ -helix and  $\beta$ -pleated structures of proteins are classified as  
 (a) primary structure (b) secondary structure  
 (c) tertiary structure (d) quaternary structure.

#### Matrix Match Type

29. Match the column I with column II and select the correct option.

	Column I		Column II
(A)	Riboflavin	(i)	Beri beri
(B)	Thiamine	(ii)	Scurvy
(C)	Pyridoxine	(iii)	Cheilosis
(D)	Ascorbic acid	(iv)	Convulsions

(a) (A)  $\rightarrow$  i, (B)  $\rightarrow$  iv, (C)  $\rightarrow$  iii, (D)  $\rightarrow$  ii  
 (b) (A)  $\rightarrow$  iii, (B)  $\rightarrow$  i, (C)  $\rightarrow$  iv, (D)  $\rightarrow$  ii  
 (c) (A)  $\rightarrow$  iii, (B)  $\rightarrow$  iv, (C)  $\rightarrow$  i, (D)  $\rightarrow$  ii  
 (d) (A)  $\rightarrow$  iv, (B)  $\rightarrow$  ii, (C)  $\rightarrow$  i, (D)  $\rightarrow$  iii

30. Match the column I with column II and select the correct option.

	Column I		Column II
(A)	Natural polymer	(i)	Rayon
(B)	Addition polymer	(ii)	Bakelite
(C)	Copolymer	(iii)	Silk
(D)	Semi-synthetic polymer	(iv)	Neoprene

(a) (A)  $\rightarrow$  (i), (B)  $\rightarrow$  (ii), (C)  $\rightarrow$  (iv), (D)  $\rightarrow$  (iii)  
 (b) (A)  $\rightarrow$  (iii), (B)  $\rightarrow$  (iv), (C)  $\rightarrow$  (ii), (D)  $\rightarrow$  (i)  
 (c) (A)  $\rightarrow$  (ii), (B)  $\rightarrow$  (iii), (C)  $\rightarrow$  (i), (D)  $\rightarrow$  (iv)  
 (d) (A)  $\rightarrow$  (iv), (B)  $\rightarrow$  (i), (C)  $\rightarrow$  (iii), (D)  $\rightarrow$  (ii)



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 No. of questions correct .....  
 Marks scored in percentage .....

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74-60%	SATISFACTORY!	You need to score more next time.
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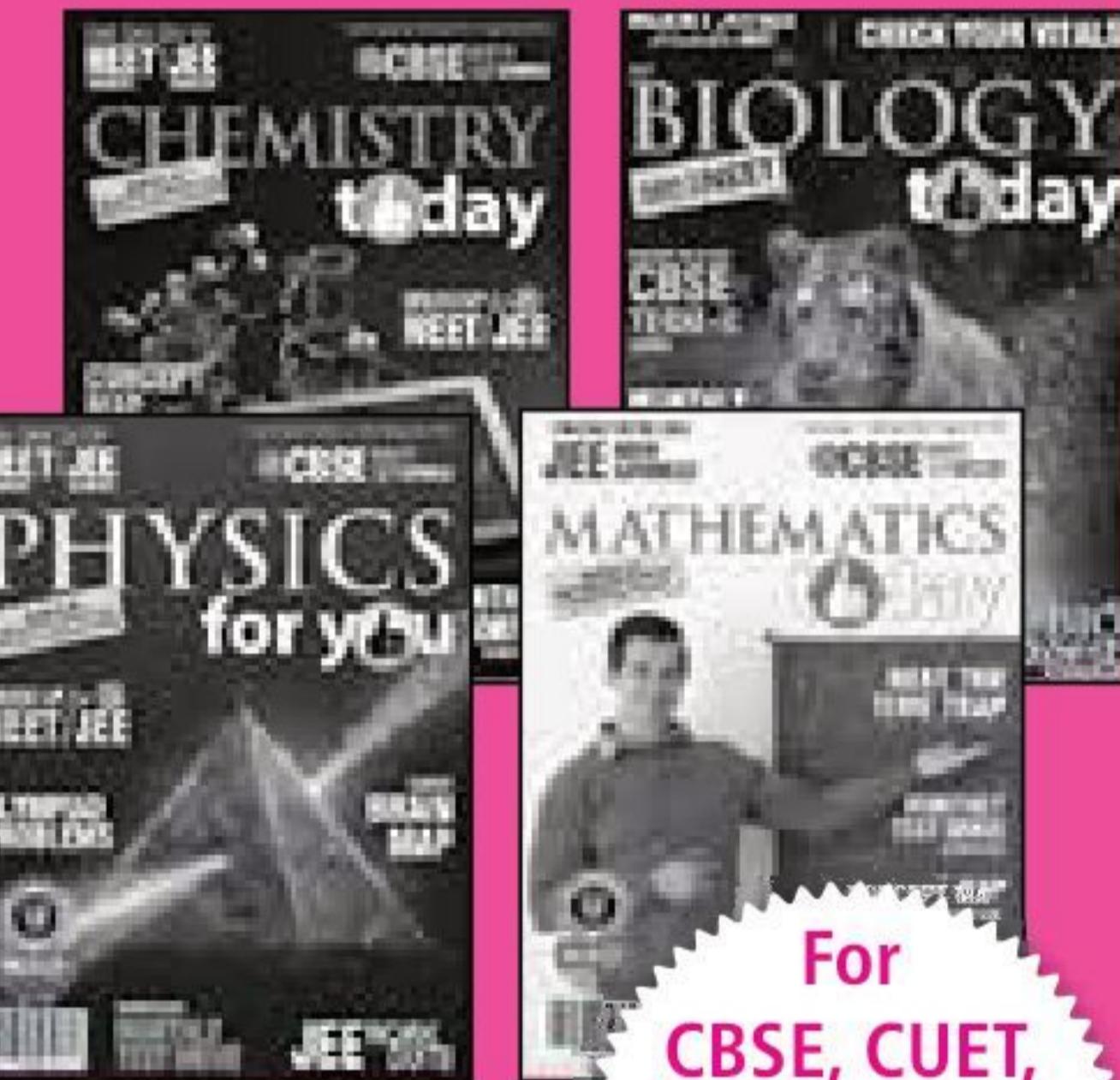


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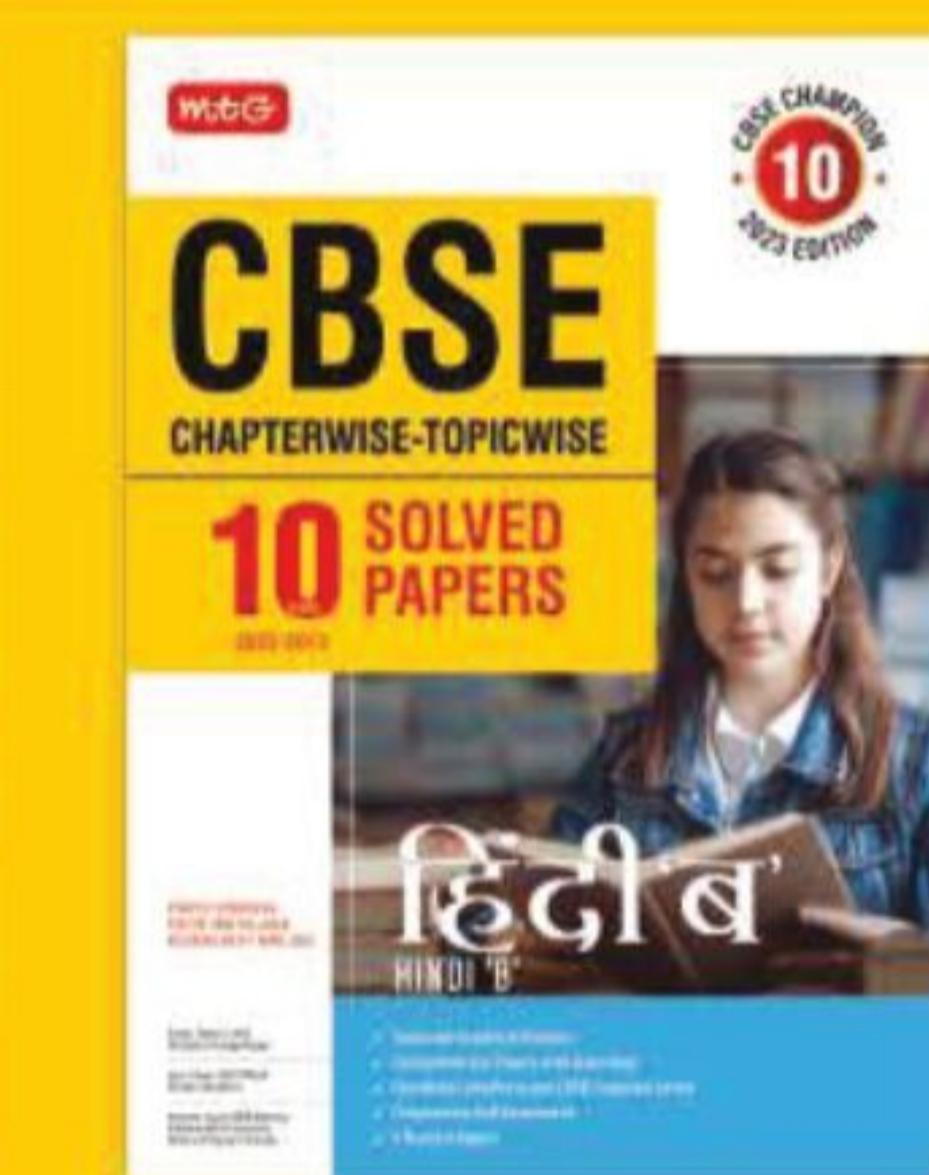
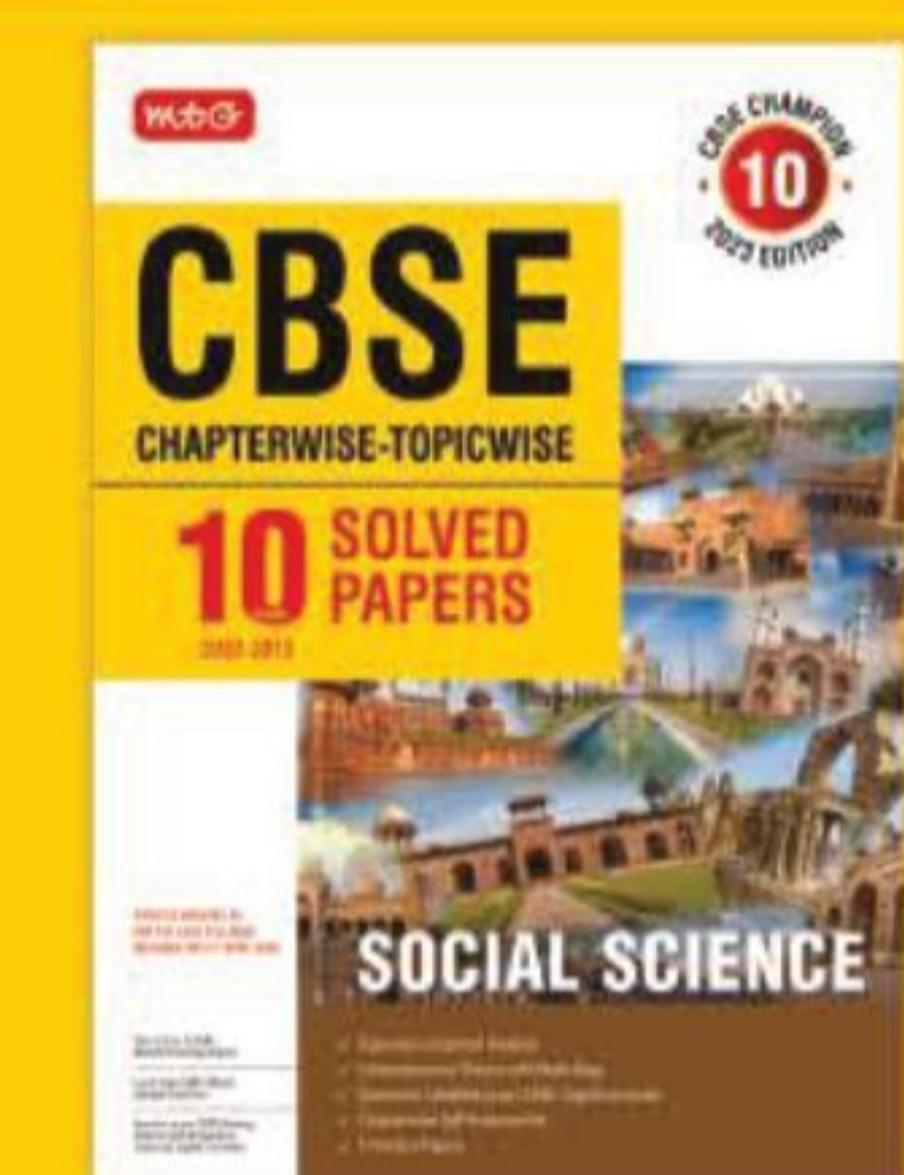
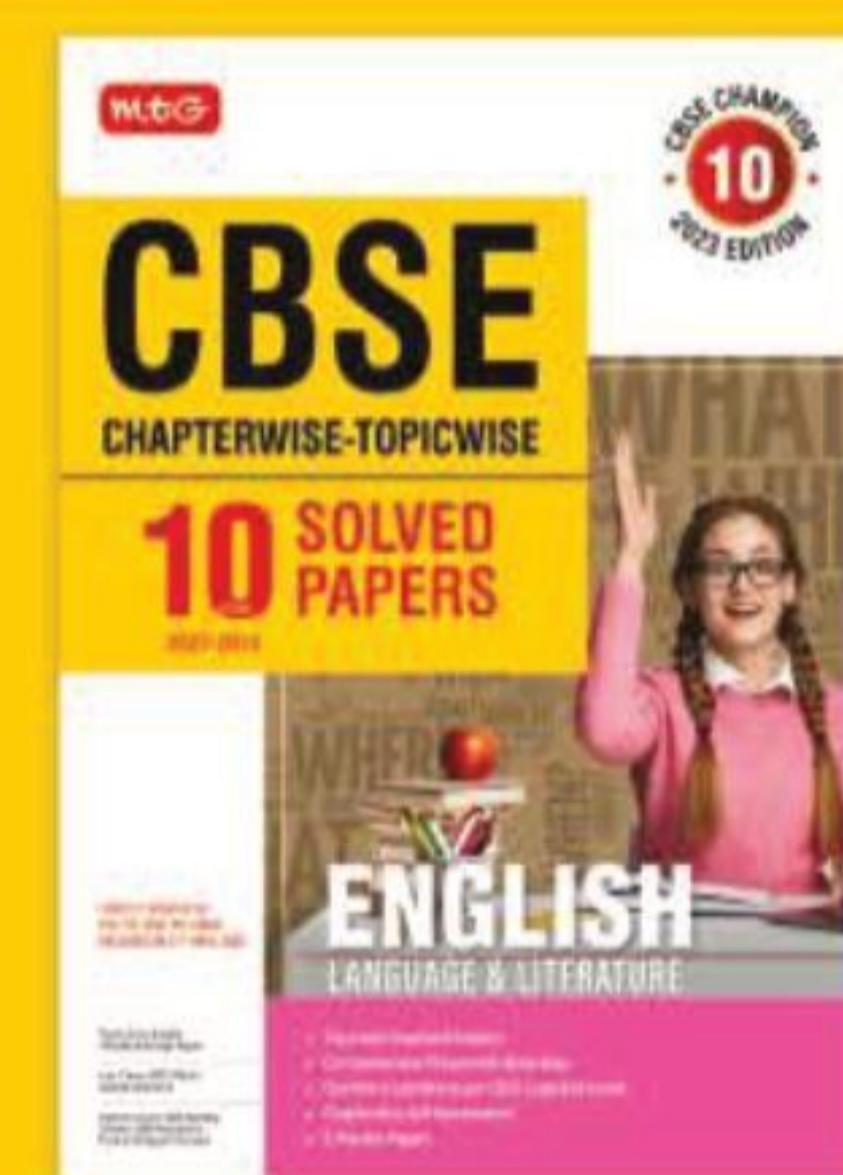
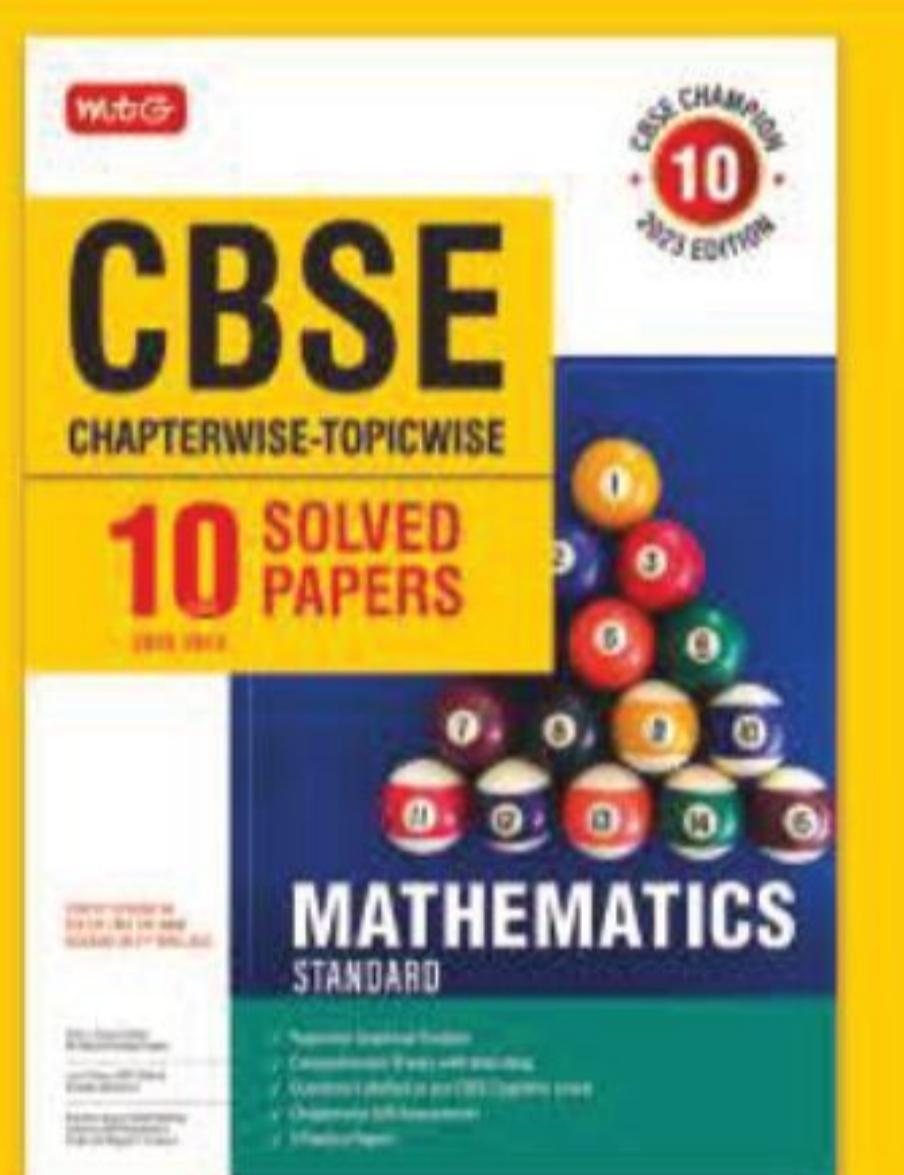
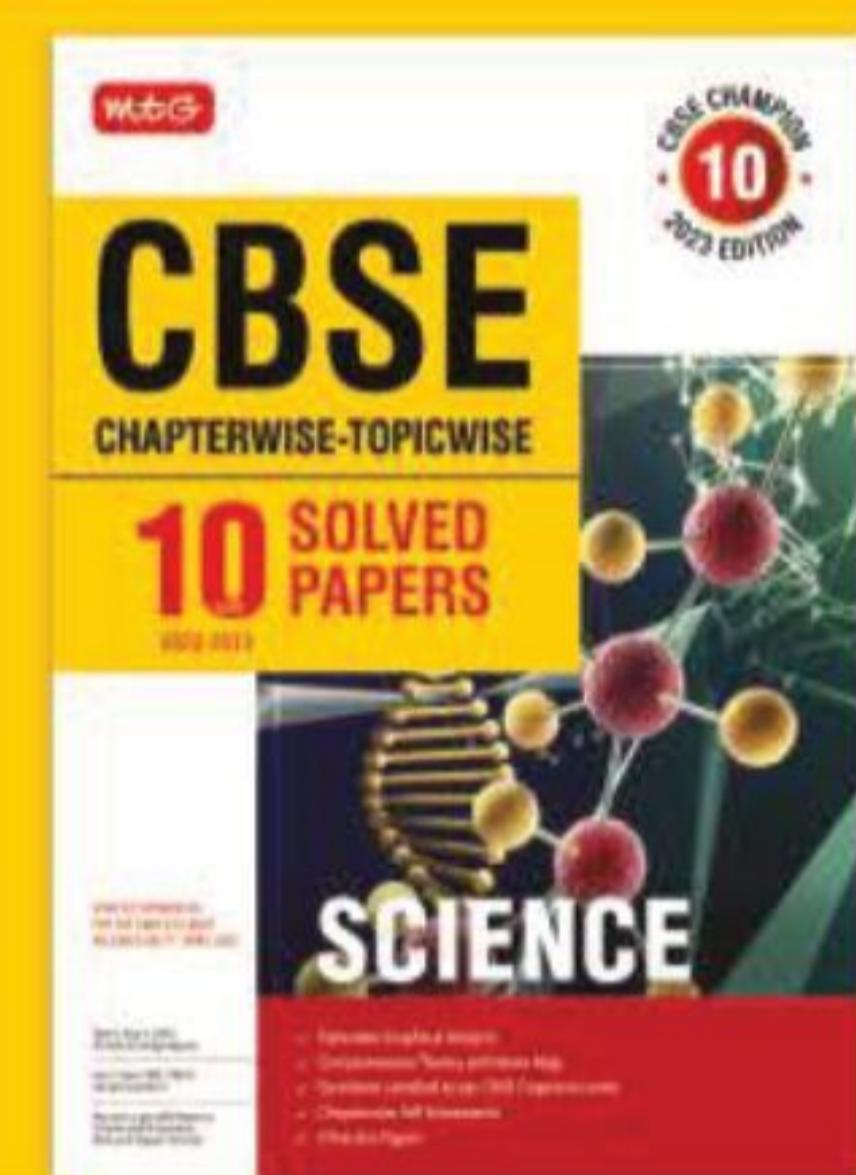
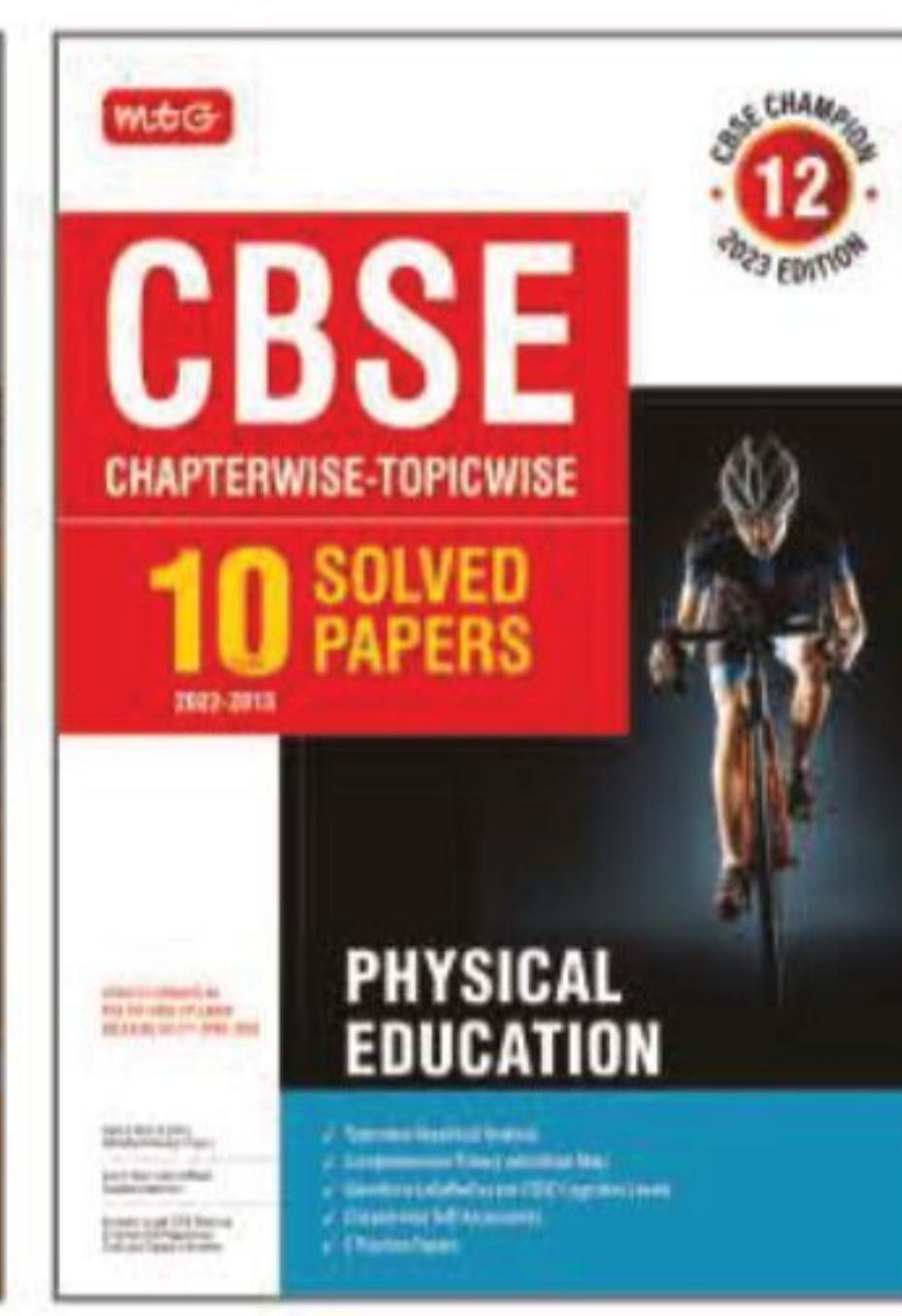
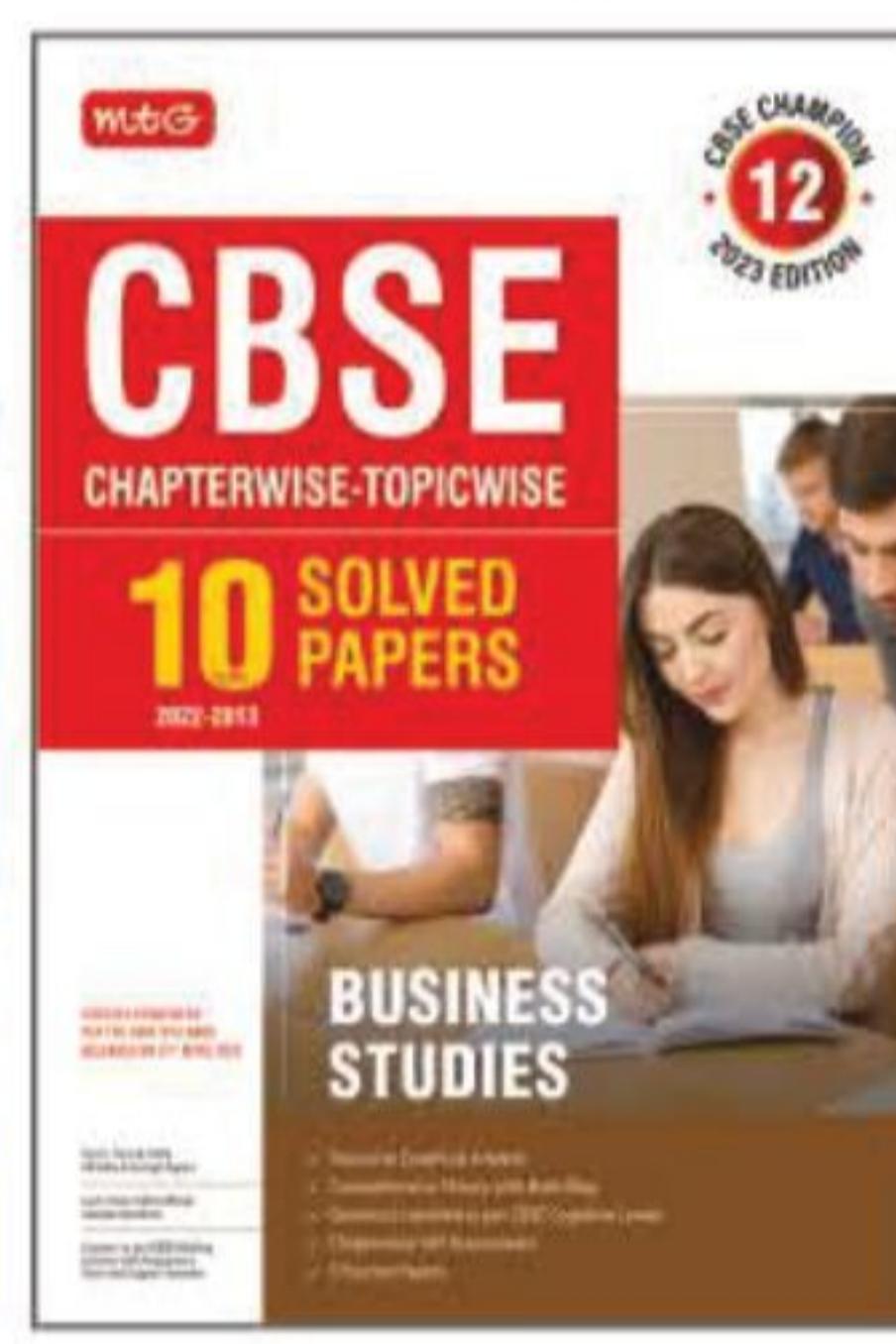
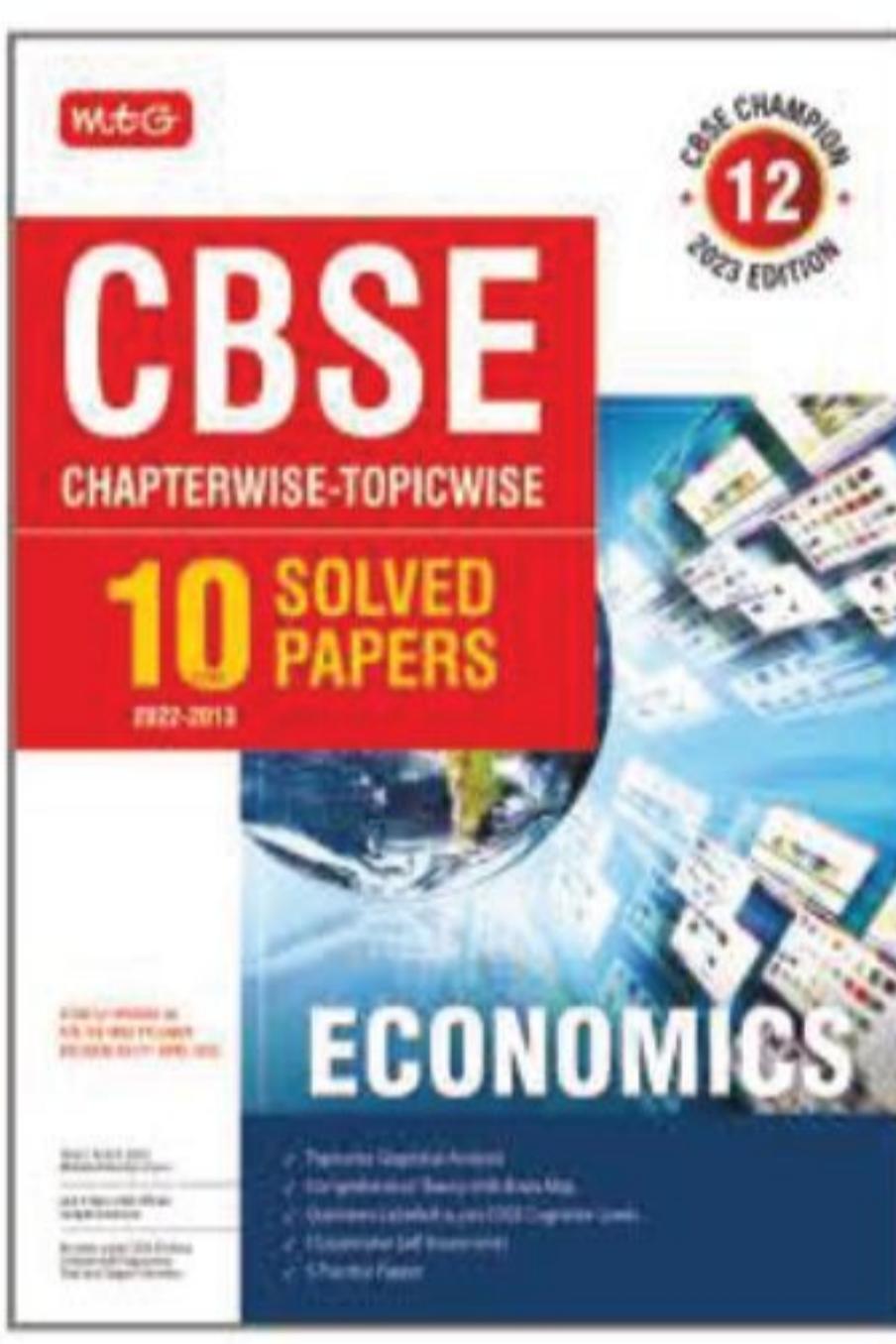
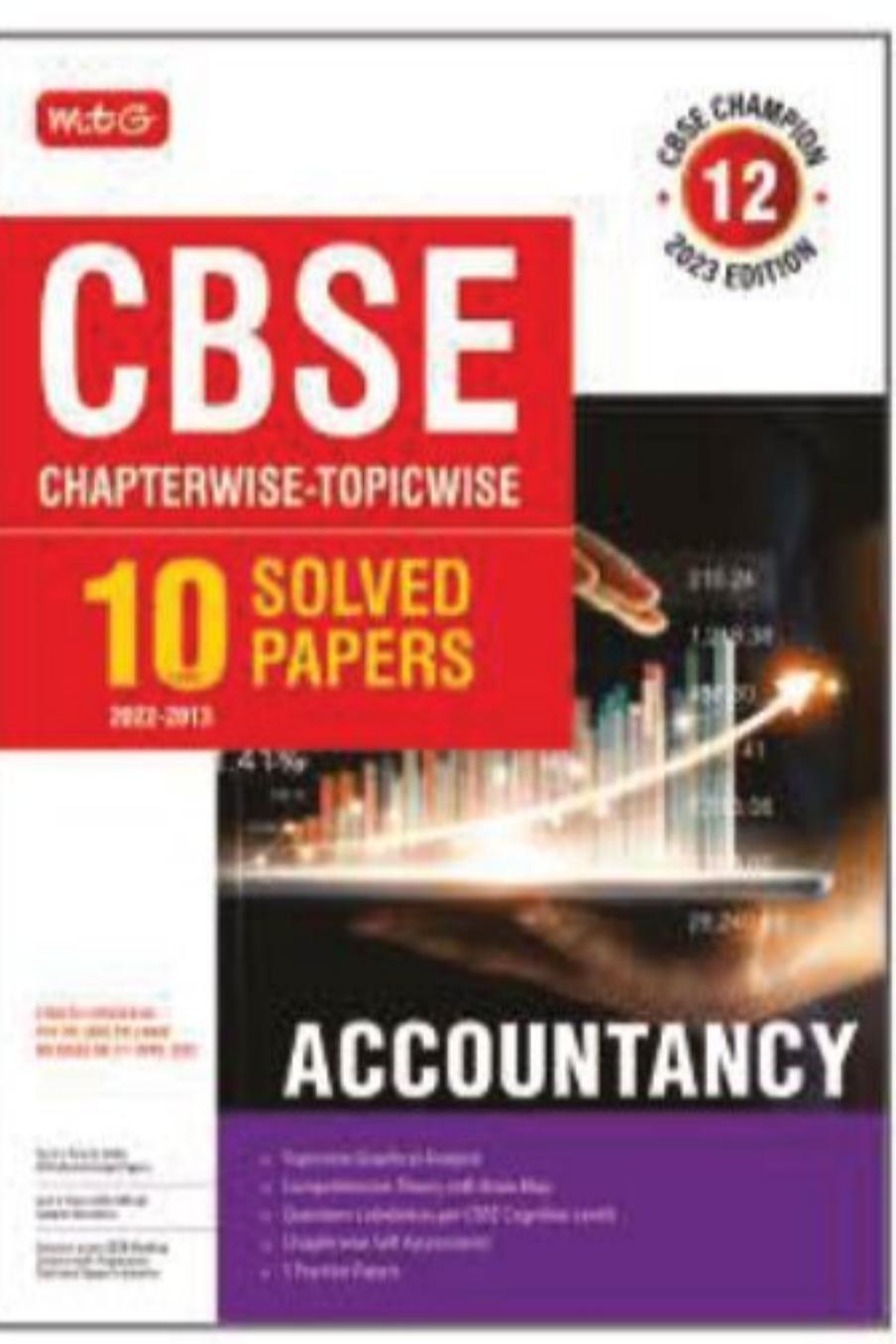
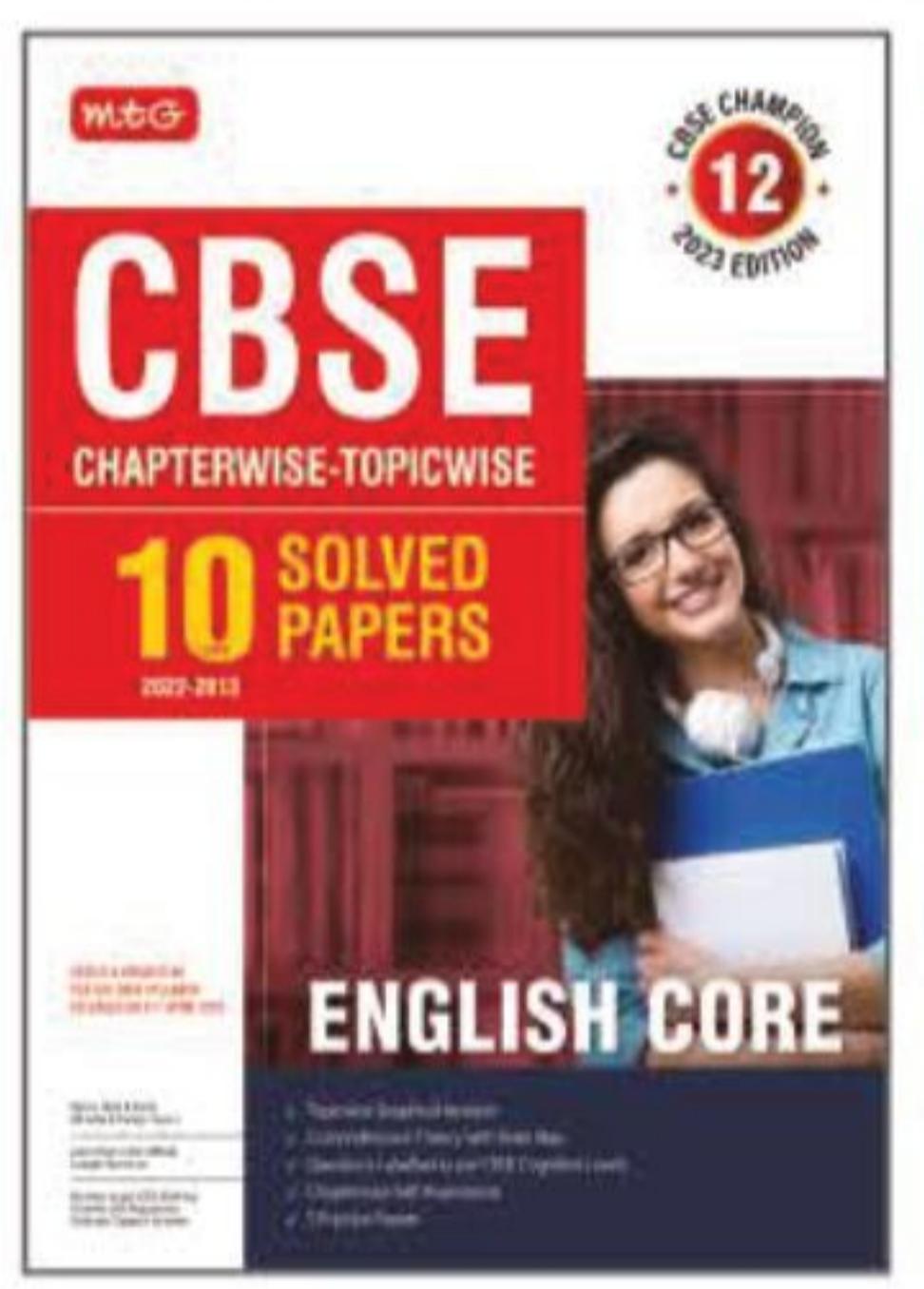
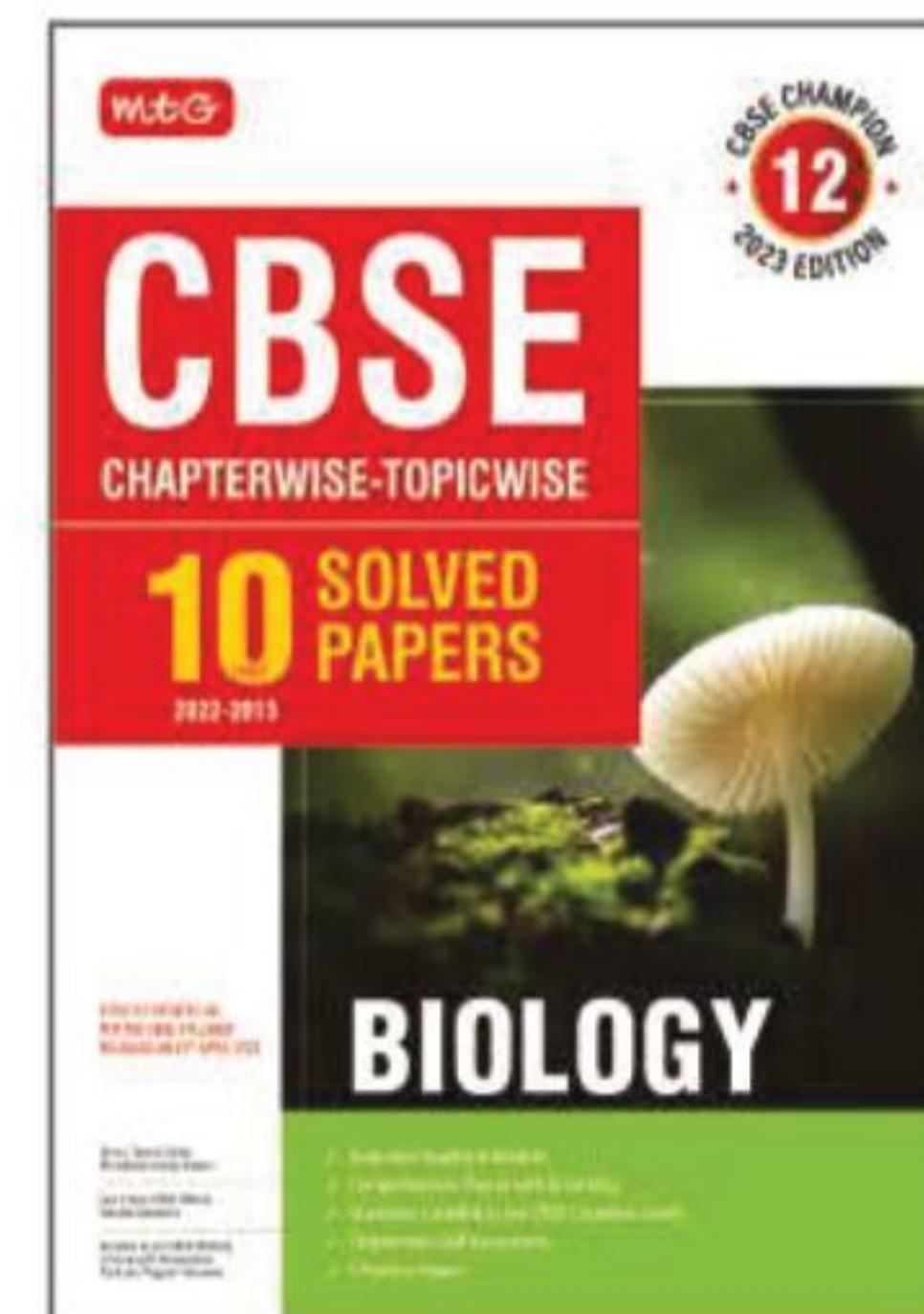
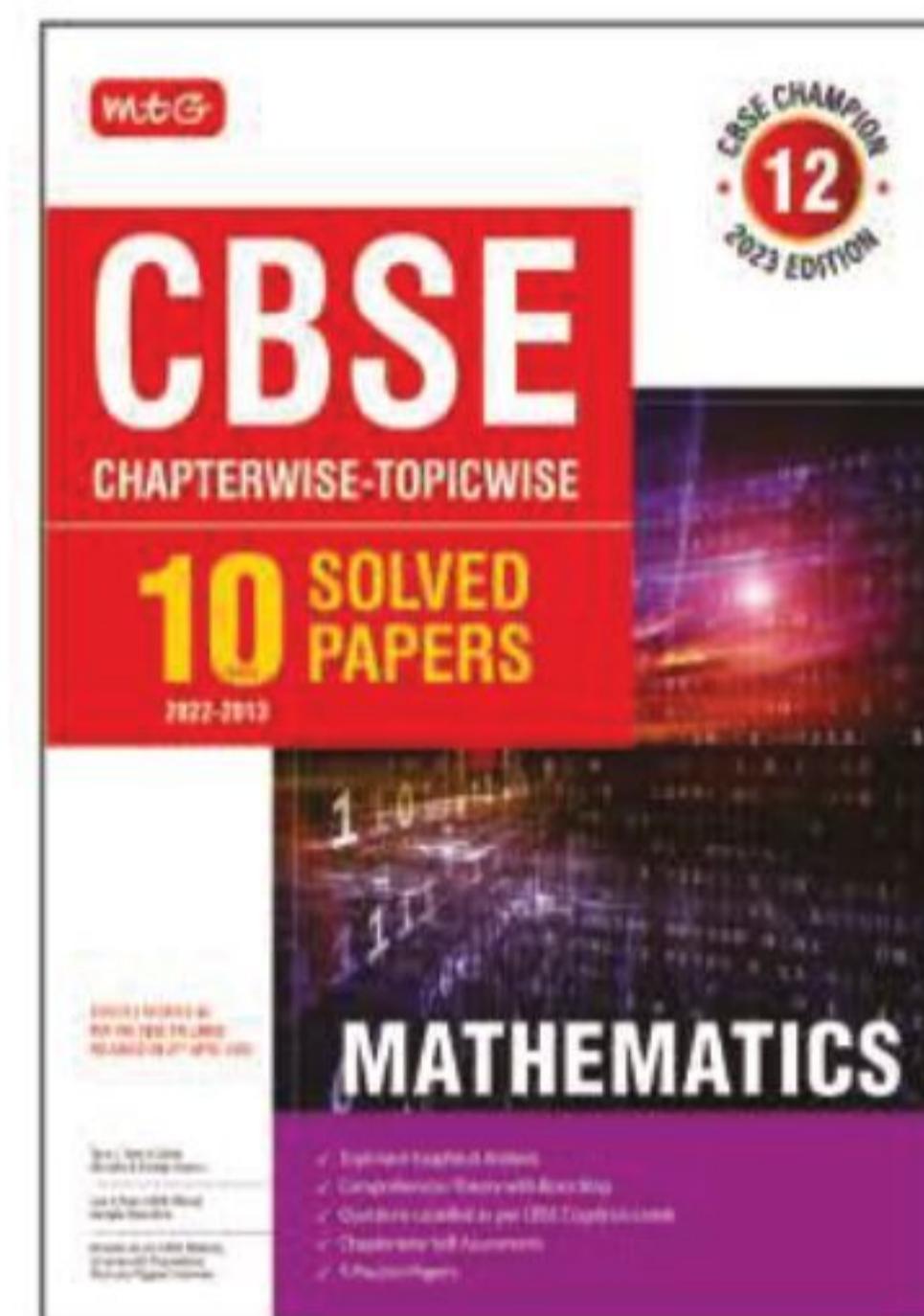
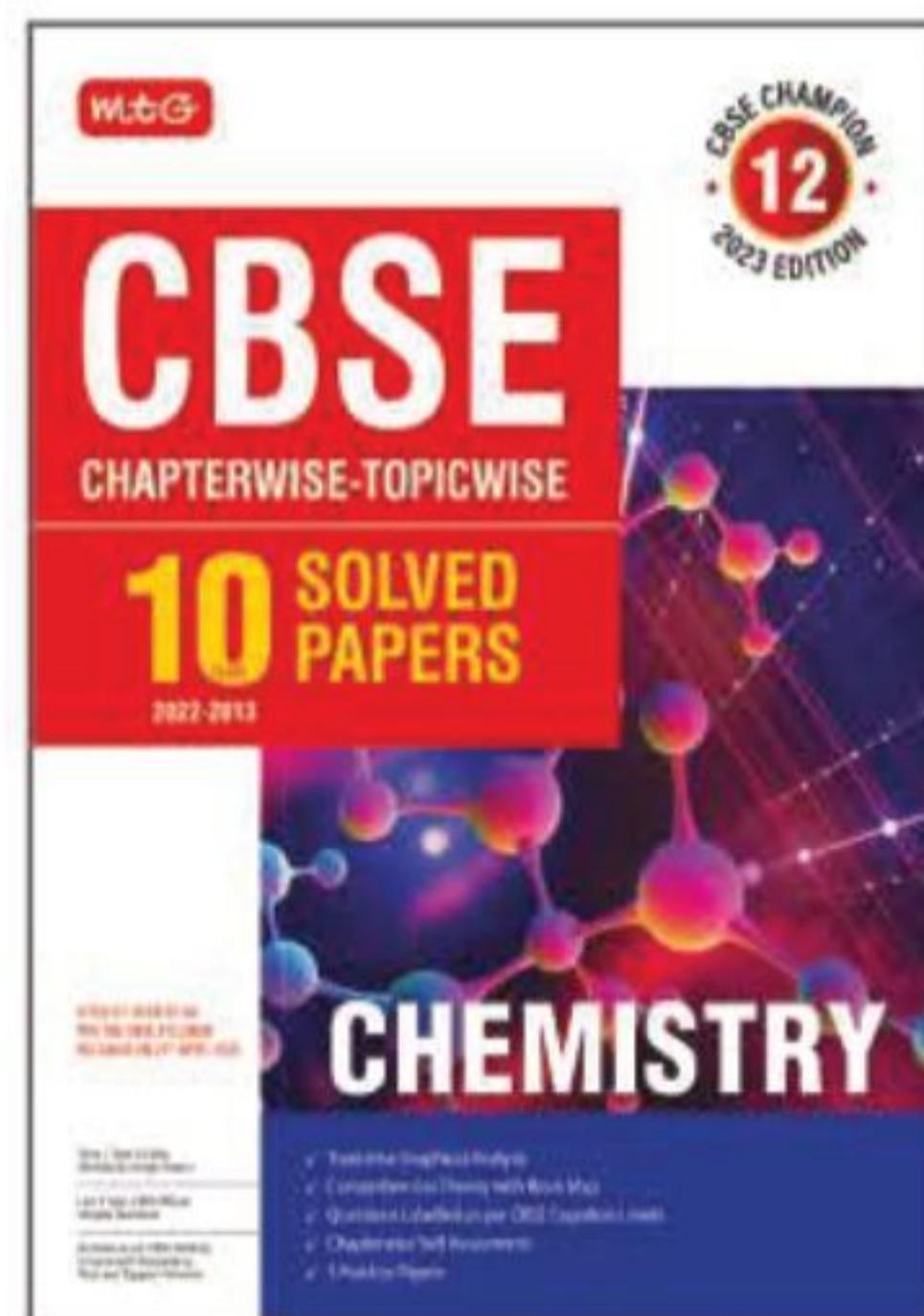
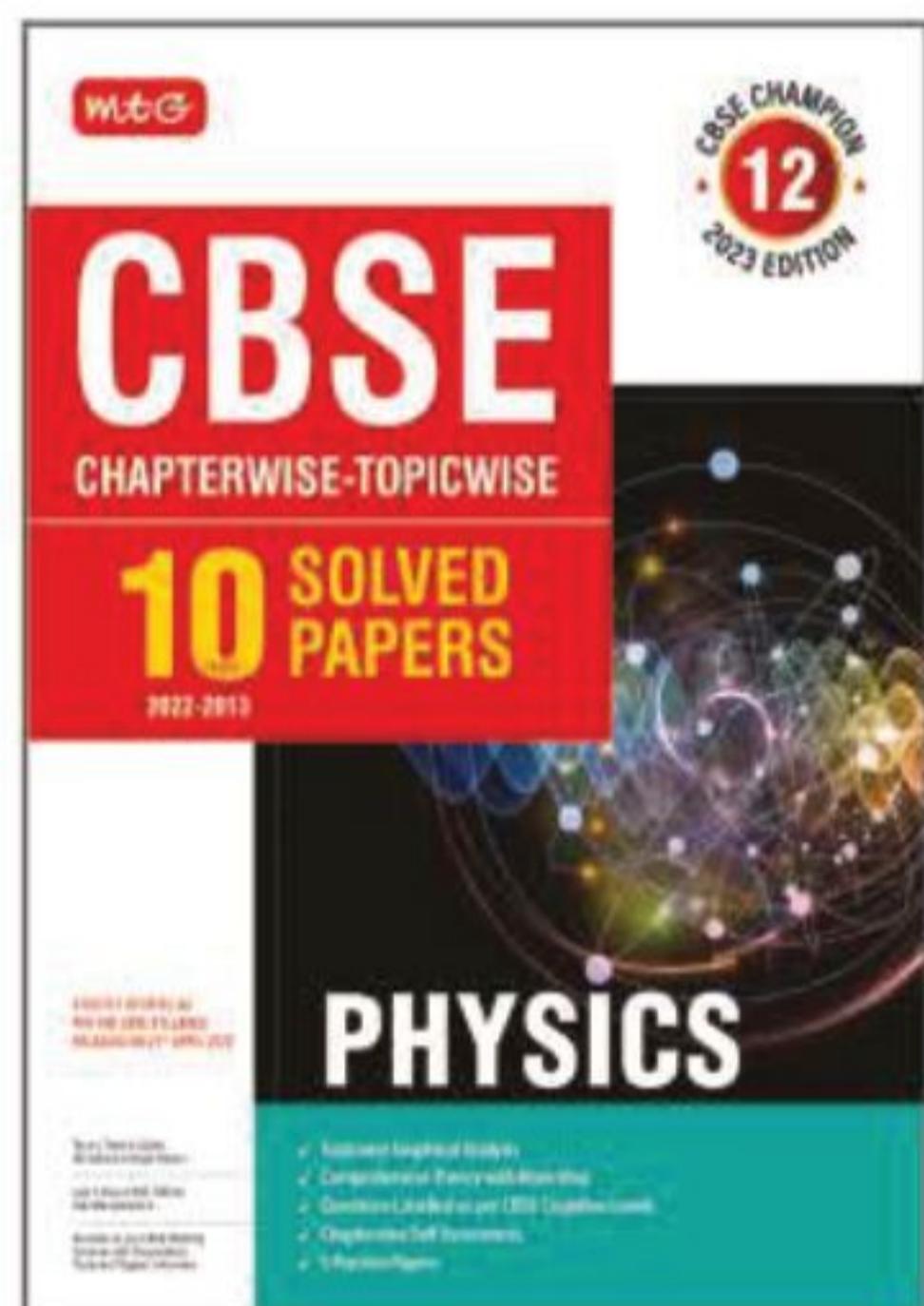
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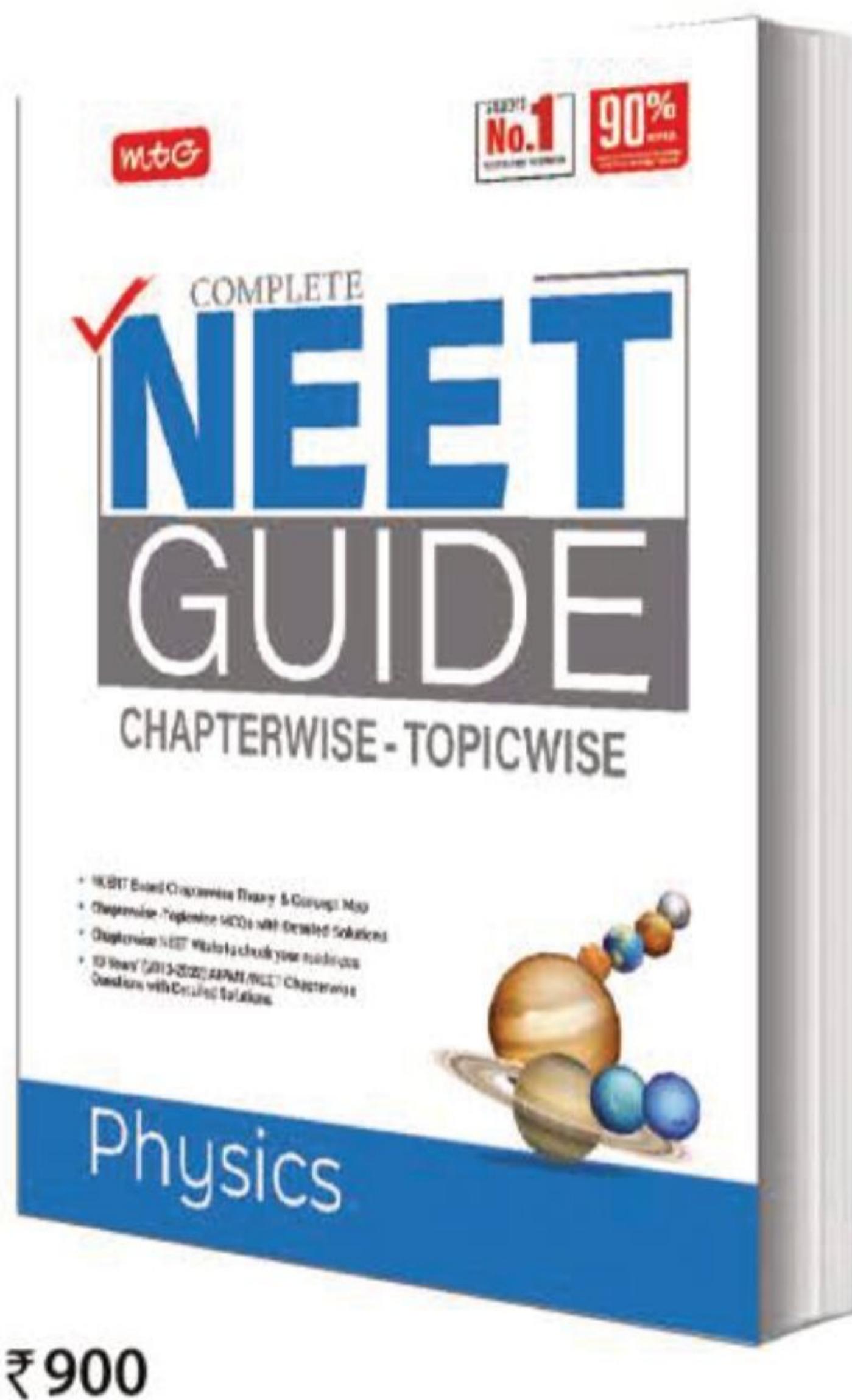
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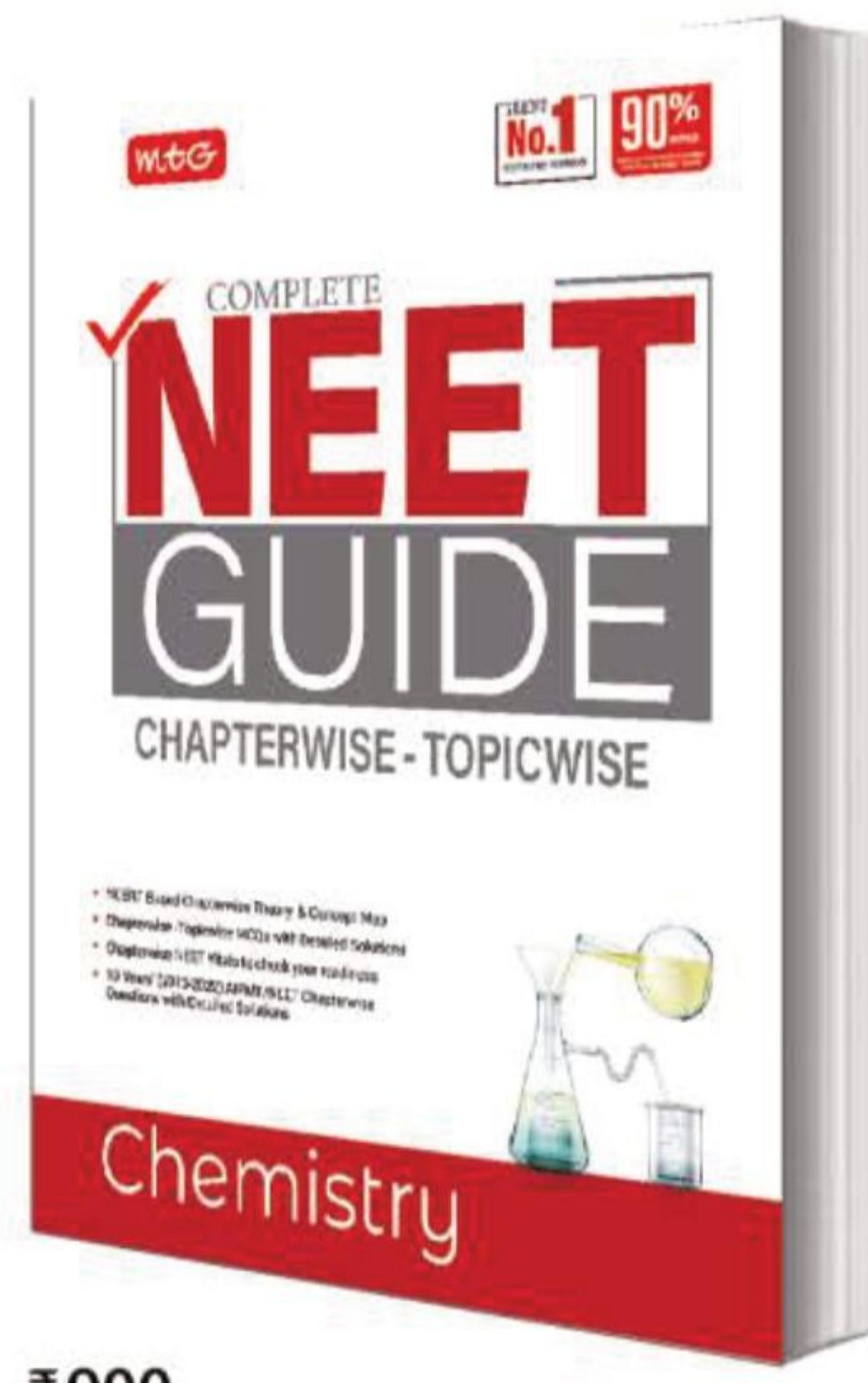
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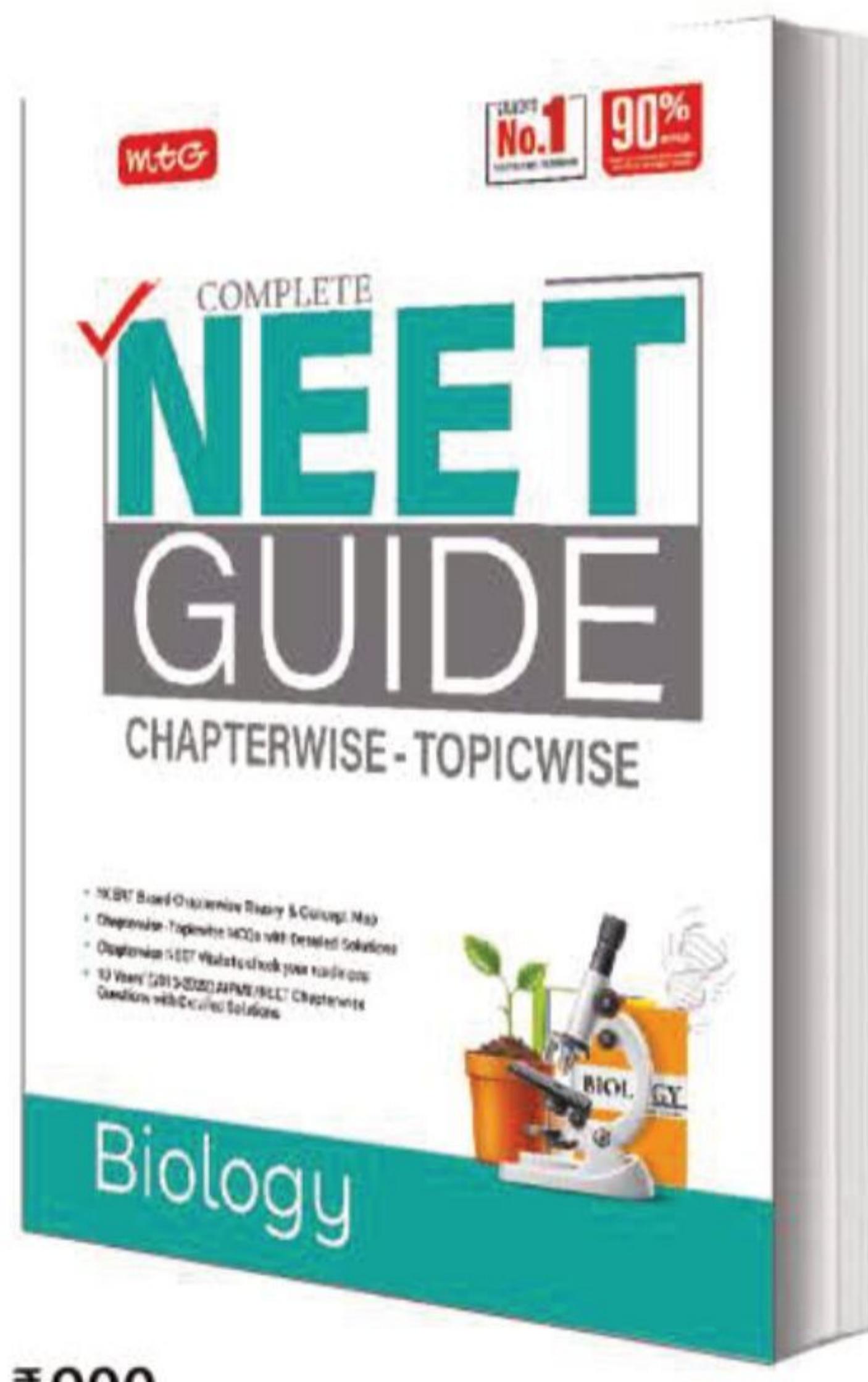
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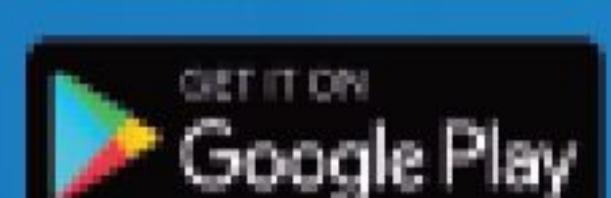
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